S. HRG. 116–295

PATHWAYS TO REESTABLISH U.S. GLOBAL LEADERSHIP IN NUCLEAR ENERGY AND S. 903, THE NUCLEAR ENERGY LEADERSHIP ACT

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED SIXTEENTH CONGRESS

FIRST SESSION

APRIL 30, 2019

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PATHWAYS TO REESTABLISH U.S. GLOBAL LEADERSHIP IN NUCLEAR ENERGY AND S. 903, THE NUCLEAR ENERGY LEADERSHIP ACT

TUESDAY, APRIL 30, 2019

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

The Committee met, pursuant to notice, at 10:07 a.m. in Room SD–366, Dirksen Senate Office Building, Hon. Lisa Murkowski, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

The CHAIRMAN. Good morning, everyone. The Committee will come to order.

We are here this morning for a dual purpose, to examine ways to reestablish U.S. leadership in nuclear energy and to receive testimony on S. 903, which is the Nuclear Energy Leadership Act, we lovingly refer to it as NELA.

America has long been a leader in the peaceful use of nuclear energy, but over time, our global role has declined. Since 2013, seven U.S. reactors have shut down before the end of their useful life and more closures are planned.

Our hopes for a nuclear renaissance, as envisioned in the Energy Policy Act of 2005—and I was a member of this Committee when Senator Domenici was leading things around here, and we talked often about that nuclear renaissance and we were all very buoyed and encouraged at that time—but that has really paled. We have been reduced to just two reactors currently under construction.

In the meantime, China and Russia have realized nuclear energy's immense potential and are now considered the international leaders in this space. They are deploying their current reactors at rates far beyond the U.S. They are actively demonstrating advanced reactor technologies, and they are poised to take full advantage of the estimated $740 billion in world market growth for commercial nuclear power by year 2030.

The loss of our nuclear leadership to these competitor nations means a degradation of our energy security, our economic opportunities, as well as our global security.

Here in this Committee, we have already held two hearings looking at the impact of climate change and particularly on the electric sector. But just a recognition that we are focused here about ways that we can work within this Committee's jurisdiction to lower our emissions and a recognition that if you are seeking lower emissions, look no further than nuclear energy as part of that energy portfolio mix.

My Nuclear Energy Leadership Act, which is cosponsored by Senator Booker and 16 additional Senators, is designed to reposition the United States as the undisputed world leader in advanced nuclear technology. It will focus the efforts of the Department of Energy on demonstrating advanced reactor concepts, establish a high-assay, low-enriched uranium fuel program, authorize the versatile test reactor, extend university scholarships and fellowship programs as well as allow the Federal Government to be an early adopter of advanced reactors for national security purposes.

I would like to thank my colleague, Senator Manchin, also Senators Risch, Alexander, and Gardner, among others, for cosponsoring this legislation. We have also received letters of support from an array of companies and stakeholders, including ClearPath, the Nuclear Industry Council, TerraPower, Terrestrial, the U.S. Chamber of Commerce. I am going to include all of their letters of support as part of the record.

[Letters of support for S. 903 follow.]

COLLEGE OF ENGINEERING
NUCLEAR ENGINEERING & RADIOLOGICAL SCIENCES
UNIVERSITY OF MICHIGAN

Todd Allen
Glenn F. and Gladys H. Knoll Department Chair
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24 April 2019

Senator Lisa Murkowski
522 Hart Senate Office Building
Washington, D.C. 20510

Senator Joseph Manchin
306 Hart Senate Office Building
Washington, D.C. 20510

Dear Senators Murkowski and Manchin:

I am writing to voice strong support for your recently introduced legislation, S.3422 - Nuclear Energy Leadership Act (NELA). As the Chair of the nation's #1 ranked nuclear engineering program and the Director of the new Fastest Path to Zero Initiative, I believe that nuclear energy is a critical part of a well-structured modern energy system, providing clean energy and supporting vital U.S. jobs.

To be effective, nuclear energy must provide a wider range of products in addition to the traditional large electricity production machines currently in commercial operation. Over the past five years, a community of innovators has begun to emerge that is altering the way we develop and commercialize nuclear technologies. Approximately seventy-five companies are spending private funds on nuclear innovation, partnering with our national laboratories and universities to accelerate the modernization of our nuclear fleet. While these technologists work to develop 21st century nuclear products, we need to support them with sound public policy that encourages their commercial deployment. NELA provides many critical policy elements that specifically:

- Provides for power purchase agreements that allow demonstrations to be built and encourages commercial companies to drive down costs to compete for these power sales. These agreements should be effective in a manner similar to those program that drove down prices of solar and wind technologies.
- Demands improvements in the way we strategically spend federal research and development funds
- Creates a minimum amount of nuclear fuel to allow new reactor technologies to build and operate first generation plants
- Recognizes the importance of the U.S. universities in advancing nuclear technology and educating the next generation of technology leaders.

Thank you for introducing this important legislation, which is an important step in ensuring the U.S. nuclear industry leads in innovation and development of new commercial products. If I can be of any assistance in providing more information or answering questions about how this legislation will impact research being done at universities like the University of Michigan, please let me know. I look forward to working with you in support of NELA as it moves toward law.

Sincerely,

Todd Allen
Glenn F. and Gladys H. Knoll Department Chair
Department of Nuclear Engineering & Radiological Sciences
Director, Fastest Path to Zero Initiative

CHAMBER OF COMMERCE
OF THE
UNITED STATES OF AMERICA

NEIL L. BRADLEY
EXECUTIVE VICE PRESIDENT &
CHIEF POLICY OFFICER

1615 H STREET, NW
WASHINGTON, DC 20062
(202) 463-5310

April 29, 2019

The Honorable Lisa Murkowski
Chair
Committee on Energy and
Natural Resources
United States Senate
Washington, DC 20510

The Honorable Joe Manchin
Ranking Member
Committee on Energy and
Natural Resources
United States Senate
Washington, D.C 20510

Dear Chair Murkowski and Ranking Member Manchin:

The U.S. Chamber of Commerce supports S. 903, the Nuclear Energy Leadership Act ("NELA"). With 16 bipartisan cosponsors, NELA embodies the across-the-aisle collaboration necessary to develop effective legislation that will move America forward and enhance our global competitiveness.

NELA would bolster America's historic leadership in nuclear energy by developing next-generation nuclear energy resources. While other countries have developed competing nuclear industries, our domestic development and use of nuclear generation has stagnated. NELA would tip the balance back in our favor.

NELA would require the Department of Energy to create a ten-year nuclear energy strategic plan, while fostering the development of advanced reactor demonstration projects, including a fast neutron source. This legislation would also establish an advanced nuclear fuel security program and authorize long-term nuclear power purchase agreements. NELA would facilitate the nuclear industry's design and deployment of advanced reactor concepts and establish the University Nuclear Leadership Program, which would harness the technical know-how of our domestic innovators while training tomorrow's advanced nuclear developers and operators.

In light of the challenges posed by climate change, innovative nuclear energy technologies hold great promise to provide reliable, affordable, safe, and carbon-free electricity to power America forward. As such, the Chamber urges the Committee to favorably report S. 903 to the full Senate.

Sincerely,

Neil L. Bradley

cc: Members of the Senate Energy and Natural Resources Committee

CLEARPATH ACTION

April 29, 2019

Senator Lisa Murkowski	Senator Joe Manchin
Chairman	Ranking Member
522 Hart Senate Office Building	306 Hart Senate Office Building
Washington, DC 20510	Washington, DC 20510

Dear Chairman Murkowski and Ranking Member Manchin,

On behalf of ClearPath Action, a 501(c)4 organization working to accelerate conservative policies that accelerate clean energy innovation, I am writing to support *the Nuclear Energy Leadership Act (NELA)*, which takes several crucial steps to ensure a future for American advanced nuclear energy technologies.

A new generation of nuclear reactors is being developed by the private sector. These advanced reactors are far more efficient and scalable than current designs, and offer significant safety and cost benefits.

While America's nuclear companies are growing, advanced reactors are also being rapidly developed abroad – Russia already operates two, and both China and India have multiple advanced reactors under construction. Without ensuring the appropriate infrastructure is in place the U.S. could lose its dominant role in nuclear energy. To avoid that eventuality, NELA takes several key actions to advance new clean baseload nuclear power:

- Sets an ambitious goal for the Department of Energy to support the research, development, and demonstration of multiple advanced reactors – two by 2025 and another two to five by 2035;
- Creates a new initiative to guarantee fuel availability for initial deployments of advanced reactors (no private infrastructure for this fuel currently exists in the U.S.);
- Directs the DOE to construct a versatile test reactor — a crucial research and development (R&D) tool that the private sector needs, and is unable to provide on its own, to test these state of the art designs;
- Modernizes government power contracting mechanisms for advanced clean energy and;
- Reauthorizes education and workforce programs related to nuclear energy.

We must keep American innovation and know-how here at home, and this bill is an important first step to maintaining American dominance in nuclear energy.

Sincerely,

Rich Powell
Executive Director, ClearPath Action

framatome

April 29, 2019

Honorable Lisa Murkowski
Chairman
Committee on Energy and Natural Resources
304 Dirksen Senate Office Building
Washington, DC 20510

Honorable Joe Manchin
Ranking Member
Committee on Energy and Natural Resources
304 Dirksen Senate Office Building
Washington, DC 20510

Dear Chairman Murkowski and Ranking Member Manchin,

I am writing to express Framatome Inc.'s support for Senate bill 903, the Nuclear Energy Leadership Act. As a leading company in the nuclear industry committed to delivering innovative solutions and value-added technologies to support the operation of the commercial nuclear fleet and prepare for the next generation of nuclear power plants, Framatome values the vision laid out in the legislation. We support the effort to provide the infrastructure and commercial pathway for the next generation of nuclear technology in the United States.

Framatome has partnered with a fellow Virginia company, Lightbridge Corporation, to create Enfission, a joint venture developing nuclear fuel assemblies based on Lightbridge-designed metallic fuel technology. Establishing a long term domestic supply of High Assay Low Enriched Uranium to support the next generation of nuclear fuel technology is critical, and we commend the focus given to this subject in the legislation.

As a company with over 50 years of proven experience in the U.S. industry we recognize the importance of maintaining leadership in advanced nuclear energy technology. We appreciate that the bill provides the tools, resources, and partnerships to facilitate this leadership into the future.

We thank all the bill sponsors for their support of nuclear energy and reiterate our support for passage of the bill.

Sincerely,

Gary Mignogna
President and CEO
Framatome Inc.

Framatome Inc.
3315 Old Forest Road
Lynchburg, VA 24501
Tel: (434) 832-3000

www.framatome.com

TERRESTRIAL
ENERGY USA

April 29th, 2019

The Honorable Lisa Murkowski, Chair
The Honorable Joe Manchin, Ranking Member
United States Senate
Committee on Energy and Natural Resources
Washington DC 20510

Re: Letter of Support for S.903, the Nuclear Energy Leadership Act

Dear Senator Lisa Murkowski and Senator Joe Manchin,

I am writing to express my support for S.903, the Nuclear Energy Leadership Act (NELA), which has a clear objective to reestablish the Unites States' global leadership in nuclear energy by supporting private industry in its ability to deploy advanced reactor concepts at an economically competitive cost. Terrestrial Energy USA (TEUSA) is a leading U.S. developer of a Generation IV (Gen IV) nuclear energy reactor called the Integral Molten Salt Reactor (IMSR®). For private developers of Gen IV reactors like TEUSA, robust partnerships with the National Laboratories play a critical role in development. The DOE's research network plays a vital role in America's innovation leadership by providing the seeds for innovation breakthroughs that can make Gen IV energy systems more affordable, reliable, and clean.

Many of the companies developing Gen IV reactors, such as TEUSA, are small medium enterprises (SMEs) that are market orientated and have limited capital and R&D resources. DOE and its national laboratories can play a crucial role to assist these SMEs by accelerating the development and deployment of their nuclear energy technologies by two principal means: Providing grant capital for technology development to leverage private funds, and; access to much needed laboratory facilities for demonstration projects to show the commercial capabilities of Gen IV technologies. In addition, the deployment of advanced nuclear energy designs would be bolstered by the extension of federal power purchase agreements (PPA's) from 10 years to 40 years. The current limit of 10 years for federal PPAs puts the nuclear industry at a commercial disadvantage because initial capital costs for nuclear plants are paid for over a period beyond 10 years.

The successful commercialization of Gen IV technology will advance the United States' energy independence and global competitive position. This bill helps secure the necessary government support for SMEs, like TEUSA, to deploy advanced nuclear technologies globally in a marketplace where foreign competitors already have the great benefit of government support.

Sincerely,

Simon Irish
CEO, Terrestrial Energy USA

Terrestrial Energy USA, Inc.
150 East 58th Street • Suite 2413 • New York • NY • 10155 • USA
www.TerrestrialUSA.com

From: smilmoe@aol.com
To: Reinke, Benjamin (Energy)
Cc: Keller, Annalyse (Gardner); Gidner, Courtney (Bennet)
Subject: FW: USNIC Follow -- NELA letters of support
Date: Saturday, April 27, 2019 12:55:02 PM

The Honorable Lisa Murkowski, Chair
The Honorable Joe Manchin, Ranking Member United States Senate
Committee on Energy and Natural Resources Washington DC 20510

I support the Nuclear Energy Leadership Act as described in the email from the Nuclear Industry Council.

I applaud you and my Senators Cory Gardner and William Bennet for supporting the bill. I only hope it is not too late. Please act quickly.

All the best,

CJ Milmoe
Milmoe Consulting Services, LLC PO Box 5622
Breckenridge, CO 80424
smilmoe@aol.com 910-262-3512

MARIA KORSNICK
President and Chief Executive Officer
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NUCLEAR ENERGY INSTITUTE

April 26, 2019

The Honorable Lisa Murkowski
Chairman
Committee on Energy and Natural Resources
U.S. Senate
304 Dirksen Senate Building
Washington, D.C. 20510

The Honorable Joe Manchin
Ranking Member
Committee on Energy and Natural Resources
U.S. Senate
304 Dirksen Senate Building
Washington, D.C. 20510

Dear Chairman Murkowski and Ranking Member Manchin:

On behalf of the commercial nuclear energy industry, the Nuclear Energy Institute (NEI)[1] expresses its support for the Nuclear Energy Leadership Act. We strongly support this bipartisan effort to accelerate the development of advanced nuclear reactor technologies.

Commercial nuclear energy is the source of nearly 20 percent of our nation's electricity and more than half of our carbon-free electricity. Nuclear energy facilities demonstrate unmatched reliability by operating with an average capacity factor of more than 90 percent—higher than all other electricity sources. And nuclear energy facilities are not only more efficient and cleaner; they also employ more workers, an average of 400-700 permanent jobs per unit, at 36-percent-higher wages than similar jobs in the local area.

Nuclear energy in this country is at a crossroads. The United States is in a race with other countries to develop, commercialize and deploy advanced reactor technologies. Supporting the development of advanced reactor technologies is crucial to maintaining U.S. technological leadership internationally. The American nuclear industry is competing globally with state-owned enterprises and businesses that are often heavily subsidized by their governments.

[1] The Nuclear Energy Institute (NEI) is responsible for establishing unified policy on behalf of its members relating to matters affecting the nuclear energy industry, including the regulatory aspects of generic operational and technical issues. NEI's members include entities licensed to operate commercial nuclear power plants in the United States, nuclear plant designers, major architect and engineering firms, fuel cycle facilities, nuclear materials licensees, and other organizations involved in the nuclear energy industry.

NELA will strengthen the domestic nuclear industry and send a strong message that the United States is committed to remain a leader in nuclear energy technology.

This bill will bolster the research and development infrastructure in the United States while supporting American innovation. It will also provide a much-needed mandate for advanced nuclear demonstration projects that will encourage the private sector to continue to invest in innovative nuclear technologies. The efforts of Congress to set the stage for developing and deploying innovative nuclear reactor technologies are important, timely and extremely valuable.

We thank the bill's sponsors for their initiative and urge all Senators to support its passage.

Yours very sincerely,

Maria Korsnick

Maria Korsnick

NEDHO

Nuclear Engineering Department Heads Organization

April 29, 2019

Senator Lisa Murkowski
522 Hart Senate Office Building
Washington, D.C. 20510

Senator Joseph Manchin
306 Hart Senate Office Building
Washington, D.C. 20510

Dear Senator Murkowski and Senator Manchin:

We write to express our strong support for the Nuclear Energy Leadership Act (NELA) that you have recently introduced and which we believe will be extremely beneficial to the country. The generation of electricity from nuclear power is essential to achieving this country's goals of clean, reliable and economic energy production.

While we support NELA in its entirety, the legislation you have introduced is especially beneficial in allowing long term power purchases, which is a much belated recognition of the long-term benefits of nuclear power. We also recognize and strongly support the provision in the legislation for the research and development of advanced reactors to re-establish our preeminence in the world.

Finally, we especially recognize the provision for workforce development. In our role as nuclear engineering educators, we see and help develop the young engineers and scientists of tomorrow who are eager to make a difference and who will be very much encouraged by the passage of this Act.

Please let us know if we can help you in any way by providing examples and statistics or answering any questions you may have.

Sincerely,

Arthur T. Motta
NEDHO Chair 2018-2019,
Chair of Nuclear Engineering,
Penn State University

Steven Biegalski
Steven Biegalski
NEDHO Vice-Chair/Chair Elect 2018-2019,
Nuclear and Radiological Engineering and Medical Physics Program Chair,
Georgia Tech

NEDHO

Nuclear Engineering Department Heads Organization

The Nuclear Engineering Department Heads Organization (NEDHO) congregates heads of nuclear engineering schools, departments, and programs in North America to address issues facing academic programs in nuclear science and engineering.

Officers: Arthur T. Motta (Chair), The Pennsylvania State University
Steven Biegalski (Vice-Chair/Chair Elect), Georgia Institute of Technology
Kathryn A. Higley (Immediate Past Chair), Oregon State University
Gilbert Brown (Treasurer), University of Massachusetts-Lowell

Kathryn A. Higley
Immediate Past Chair, NEDHO Chair 2017-2018,
Rickert Professor and Head, School of Nuclear Science and Engineering,
Oregon State University

Todd R. Allen
Glenn F. and Gladys H. Knoll Department Chair of Nuclear Engineering and Radiological Sciences,
University of Michigan

J. Wesley Hines
Nuclear Engineering Department Head,
University of Tennessee

Kostadin N. Ivanov
Nuclear Engineering Department, Head,
North Carolina State University

Peter Hosemann
Nuclear Engineering Department, Chair
University of California at Berkeley,

NEDHO

Nuclear Engineering Department Heads Organization

Seungjin Kim
Capt. James F. McCarthy, Jr. and Cheryl E. McCarthy Head
School of Nuclear Engineering,
Purdue University

Rizwan Uddin
Professor and Department Head
Nuclear, Plasma, and Radiological Engineering,
University of Illinois at Urbana-Champaign

Douglass L. Henderson

Chair, Department of Engineering Physics,
University of Wisconsin-Madison

Dennis Whyte
Hitachi America Professor of Engineering, Head, Nuclear Science & Engineering
Massachusetts Institute of Technology

Yaron Danon
Nuclear Engineering Program Director,
Rensselaer Polytechnic Institute

Robert B. Trull Chair in Engineering
Area Coordinator, Nuclear and Radiation Engineering Program,
University of Texas at Austin

NEDHO

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Gilbert Brown (Treasurer), University of Massachusetts-Lowell

Hyoung K. Lee
Director of Nuclear Engineering Program,
Missouri S&T

Mark P. Jensen

Mark P. Jensen
Nuclear Science and Engineering Program Chair,
Colorado School of Mines

James E Baciak
Director, Nuclear Engineering Program,
University of Florida

Supathorn Phongikaroon
Director of Nuclear Engineering Programs,
Virginia Commonwealth University

Sukesh Aghara
Director, Nuclear Engineering Program,
University of Massachusetts, Lowell

NEDHO
Nuclear Engineering Department Heads Organization

Anil K. Prinja
Distinguished Professor and Chair,
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Department of Mechanical Engineering
University of South Carolina

Carol Smidts
Professor of Nuclear Engineering
Department of Aerospace and Mechanical Engineering
Ohio State University

Bahram Nassersharif
Nuclear Engineering Program Director,
University of Rhode Island

PURDUE UNIVERSITY | **Nuclear Engineering** COLLEGE OF ENGINEERING

May 2, 2019

The Honorable Lisa Murkowski
Chairwoman
U.S. Senate Committee on Energy and Natural Resources
304 Dirksen Senate Office Building
Washington, DC 20510

The Honorable Joseph Manchin
Ranking Member
U.S. Senate Committee on Energy and Natural Resources
304 Dirksen Senate Office Building
Washington, DC 20510

Dear Chairwoman Murkowski and Ranking Member Manchin:

Thank you for your efforts in advancing legislation that maintains U.S. leadership in nuclear energy. I write this letter on behalf of the School of Nuclear Engineering at Purdue University to express our enthusiastic support for S. 903, the Nuclear Energy Leadership Act (NELA).

NELA will help maintain existing nuclear power fleets, sustain our nation's technological edge in nuclear energy, strengthen U.S. global competitiveness, maintain leadership in the global nuclear engineering community, and educate and prepare the future workforce of nuclear engineers. In particular, I would like to highlight our strong support for the provisions in Section 4 that set ambitious advanced nuclear reactor research and development goals and Section 8 that establishes a University Nuclear Leadership Program. These provisions in particular will expand opportunities in both research and education, and inspire future generations to consider nuclear engineering as their future career.

For nearly six decades, the Purdue School of Nuclear Engineering has been one of the leading nuclear engineering programs in educating top-notch nuclear engineers and carrying out cutting-edge research. We have had long-standing and productive partnerships with the Department of Energy (DOE) and the Nuclear Regulatory Committee (NRC). I am excited to share that the NRC, for the first time in the U.S., approved a 100% digital instrumentation and control system for our Purdue University Reactor Number One (PUR-1) - one of the country's university-based nuclear research reactors. This was made possible by a grant from DOE's Nuclear Energy University Program. The digital upgrades will serve as a training ground for students to learn how to operate state of the art equipment as well as understand and develop tools to address potential cybersecurity vulnerabilities. Purdue is ready to meet the research and education goals set out in NELA to help develop advanced nuclear power systems.

Thank you very much for leading this effort. Please let me know how I can be of assistance in helping move forward this important piece of legislation.

Sincerely,

Seungjin Kim

Seungjin Kim

Capt. James F. McCarthy, Jr. and Cheryl E. McCarthy Head and Professor
The School of Nuclear Engineering

April 29, 2019

Honorable Lisa Murkowski, Chairman
Honorable Joe Manchin, Ranking Member
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Re: S. 903, Nuclear Energy Leadership Act

Dear Senators Murkowski and Manchin:

Though it currently supplies about 20 percent of U.S. electricity, nuclear power is headed for permanent decline. American engineers and designers have some great ideas but not enough resources and capital to figure out ways for the nuclear industry to better compete in the 21st Century. Currently, the industry is overmatched by a combination of cheaper fuels like natural gas; by wind and solar, which remain subsidized by the federal government and state governments; and by foreign companies that operate under less commercial pressure and act as foreign policy arms of their respective governments.

This is why the R Street Institute supports, with some qualification, the Nuclear Energy Leadership Act (NELA) currently scheduled for a hearing before the Senate Energy and Natural Resources Committee on Tuesday, April 30, 2019. Building on earlier laws that streamline federal regulation for advanced (Generation IV) nuclear reactors, NELA takes policy a step further by ordering the Department of Energy to develop a 10-year strategic plan to support advanced nuclear research and development goals. The bill also instructs the Energy Department to build a fast-neutron research laboratory by 2025 to test new reactor technology and advanced nuclear fuels.

Currently, the only places capable of fast-neutron testing are located in Russia and China, two competing nuclear powers that force American nuclear scientists to wait in line for experiments and have the potential to cancel visas and block or steal research at any time.

A third element of NELA targets mechanisms that benefit the marketplace for nuclear power, like extending power purchasing authority for the federal government from 10 to 40 years. These long-term agreements act as collateral for startup companies to apply for financing from banks or private investment funds.

Unfortunately, the legislation as currently written does not limit these extended power agreements (PPAs) to "advanced nuclear reactor" technology. Instead, that language can be interpreted to include current nuclear reactor technology (Generation II-III), or perhaps even non-nuclear fuels. Indeed, language in the bill would require at least one commercial nuclear reactor receiving a license from the Nuclear Regulatory Commission after January 2019 to enter into a PPA.

This language is counter to the initial impulse and motivation behind the bill, which is to give private capital new opportunities to invest in a better generation of nuclear technology that is cheaper, safer and less wasteful than that of existing Generation II reactors. Because Generation IV reactor technology is many years from commercialization, this language could be used to subsidize current nuclear reactor technology that does not deserve additional taxpayer support.

These caveats notwithstanding, the overall direction of the bill is a positive one, since it is difficult to conceive of a low-carbon economy that would reverse global emissions growth by midcentury without major growth in nuclear power.

Reasonable people no longer argue about whether climate change exists, but rather over what remedies are needed and on what scale. It is a great sign for America's future that 17 Senators from both parties see a future for nuclear power. Let's all root for this kind of bipartisanship so that Congress can reinvigorate nuclear technology aimed at solving one of the most difficult challenges facing the United States and the world.

Thank you for your time and consideration. I would be happy to answer any questions the committee or its staff may have.

Sincerely,

William Murray
Manager, Energy Policy
R Street Institute
M: 202-374-4833
wmurray@rstreet.org | www.rstreet.org

April 29, 2019

Senator Lisa Murkowski
Chairman, Senate Energy and Natural Resources Committee
522 Hart Senate Office Building
Washington, DC 20510

Senator Joe Manchin
Ranking Member, Senate Energy and Natural Resources Committee
306 Hart Senate Office Building
Washington, DC 20510

Subject: Support for S.903 the *Nuclear Energy Leadership Act*

Dear Senators Murkowski and Manchin:

SMR Start is an industry organization of potential customers and vendors working toward the deployment of light-water Small Modular Reactors (SMRs). We believe that this technology offers important and unique benefits in generating reliable, safe, and affordable carbon-free electricity. Our goal is to ensure that SMRs are a cost-competitive option in the future, with the first units operating in the 2020s.

We thank you for introducing S.903 the *Nuclear Energy Leadership Act* and we believe that this legislation is critical to the success of SMRs and other advanced nuclear technologies.

Extending the maximum term of Federal Power Purchase Agreements (PPAs) from 10 years to 40 years is one of three Federal policies that we identified as critical to building customer interest in the deployment of any first-of-a-kind nuclear reactor technology.[1] Extending the term to 40 years not only improves the ability of the Federal government to procure power from a new nuclear reactor, but also the ability to procure power from any new energy technology. The benefit to the government is the availability of new generation technologies that can provide advantages over conventional technologies. Energy resilience in particular is a critical need for many government facilities, and the pilot program will help foster the deployment of advanced reactors capable of meeting these resilience needs.

SMRs feature the ability to provide highly resilient power to Federal facilities with national security and mission critical activities. SMRs are designed to operate 24/7 365 days a year with unparalleled reliability, to withstand severe natural events, such as earthquakes and hurricanes, and to continue providing power even when the grid goes down. SMRs also offer the ability to better match new generation capacity with electric demand growth, enhance grid reliability through load following in areas with high penetration of intermittent renewables, and the ability to be deployed in diverse applications, such as the cogeneration of heat and electricity, desalination, and the generation of hydrogen.

NELA provisions supporting demonstration reactors and high assay low-enriched uranium, while not essential for SMRs, are important for the deployment of other advanced reactor technologies. While SMRs are the advanced reactor technology that is closest to deployment, we also support the

[1] The other two policies are the availability of production tax credits, and the availability of DOE loan guarantees. SMR Start's Policy Statement can be found at http://smrstart.org/wp-content/uploads/2017/02/SMR-Start-Public-Policy-on-Federal-Public-Private-Partnership.pdf

deployment of other advanced reactor technologies as they continue to mature. SMRs not only serve an important role as a near-term deployment option, but they will continue to be an important nuclear technology even after other advanced reactors enter the market. Further, the success of SMRs is necessary to the success of other advanced nuclear technologies.

Rapid development of U.S. SMR technology is also needed to reestablish the U.S. as a world leader in advanced nuclear technology and strengthen national security. The U.S. has historically been a leader in nuclear technology driving exports of reactors around the world, leading to strong domestic job creation and close relationships with host countries. Sadly, U.S. policies regarding nuclear energy over the past few decades have led to an erosion of U.S. nuclear leadership and commercial competitiveness. Today China and Russia are supplying 65% of the reactors planned or under construction around the world, compared to 7% by the U.S. This bill puts us on the path to reclaiming that mantle of leadership.

We strongly support the S.903 the *Nuclear Energy Leadership Act*. Time is of the essence and we encourage the Senate and House to pass this legislation without delay.

We would be happy to discuss this topic further.

Sincerely,

Brent Ridge
Spokesperson, SMR Start

cc

Senate Energy and Natural Resources Committee Members

TerraPower.

April 26, 2019

The Honorable Lisa Murkowski, Chair
The Honorable Joe Manchin, Ranking Member
United States Senate
Committee on Energy and Natural Resources
Washington DC 20510

Re: *TerraPower Support for Nuclear Energy Leadership Act*

Dear Chairman Murkowski and Ranking Member Manchin,

Thank you for the opportunity for TerraPower to express its support for the Nuclear Energy Leadership Act (NELA), and for the bipartisan work of the Senate Energy and Natural Resources Committee to support America's advanced nuclear industry. We are particularly excited about the accelerated demonstration timelines for advanced nuclear technologies outlined in the legislation.

TerraPower was founded by two technology visionaries, Bill Gates and Nathan Myhrvold, after an extensive, impartial technology assessment of viable, robust, and lasting solutions to one of the biggest problems we face in the coming century: climate change. Our founders determined that the projected exponential population growth will require a huge expansion in energy production. They also saw that rising temperatures and sea levels, as well as increased extreme weather events will require resilient and reliable energy sources. To meet these demands and mitigate further climate change, this energy production must also be carbon-free.

Thus, our founders concluded that nuclear energy must be a major element of the future energy mix because it is the one concentrated and sustainable source that can deliver carbon-free energy 24 hours a day, 365 days a year. Nuclear power can cleanly provide the electricity to power our homes and businesses, meet increased demand as the passenger vehicle fleet electrifies, and meet critical heat needs for industrial production. Moreover, our founders examined the risks and challenges—cost, safety, proliferation, and waste—associated with legacy nuclear technology and concluded that new designs and advanced materials, engineering and simulation could overcome all of them.

From that initial inquiry, TerraPower was born in 2006. Since then, with the generous support of our investors, we have assembled an incredible team of scientists, engineers, and computer modelers

TerraPower

who have spent over a decade designing advanced nuclear technologies to provide economic, safe, proliferation-resistant, carbon-free power at scale. In 2006 few companies were working to develop advanced nuclear energy technologies, and few policymakers were aware that advanced nuclear companies existed. Since then we have completed a significant amount of research, development and design work on what we believe will be a set of game-changing technologies. As a result of that decade of work and hundreds of millions of dollars of private investment, TerraPower has made tremendous technologic progress. Our flagship technology, the Traveling Wave Reactor (TWR), is now on the cusp of commercial readiness and prepared to enter the demonstration phase. Under NELA's framework, we hope we can make that a reality here in the U.S.

NELA rightly recognizes the importance of demonstrating advanced nuclear technology and recognizes that some of the many companies developing advanced reactors are ready to graduate to demonstration. This focus on demonstration is a key part of NELA. If the American advanced nuclear industry is going to compete with foreign reactor companies backed by their governments, we will need a strong and sustained federal partnership to cross the demonstration "valley of death." NELA's accelerated timeline for demonstration is key to America's ability to bring advanced nuclear technology to market in a timeline that matters to solve climate change. As our Chairman and founder, Bill Gates, said when NELA was introduced, "I can't overstate how important this is."

TerraPower is, obviously, excited about the Traveling Wave Reactor nearing readiness for demonstration, and our Molten Chloride Fast Reactor, which we are developing in partnership with the Department of Energy, Oak Ridge National Laboratory, Southern Company, EPRI, Idaho National Laboratory and Vanderbilt University, is also making significant progress. But, beyond our own technologic progress, we also recognize we are part of a broader advanced nuclear industry working on a variety of reactor designs with different coolants, fuels, and designs. Some of these designs are still in early stages, but, if the industry is to succeed in building out supply chains and bringing costs down, the industry collectively must continue to advance and grow. Building on the provisions of the Nuclear Energy Innovation Capabilities Act (NEICA), NELA provides opportunities for partnership on research, development and demonstration for compelling ideas at varying technology readiness levels.

NELA recognizes the appropriate federal role for expediting the development of advanced nuclear technologies. It recognizes the need to "learn by doing" and the importance of increasing the pace of developing new technologies, demonstrating more mature technologies, streamlining regulations for first-of-a-kind reactors, and expanding the role of the government in purchasing power from advanced nuclear reactors. This is consistent with how the federal government has treated other forms of emerging energy technology.

In addition to the importance of solving climate change and global energy poverty, the development of American advanced nuclear technologies will be important in meeting our national and economic security goals. Russia and China are already operating advanced generation technology, and if they continue without competition from the United States, they will become the leaders in exporting the

TerraPower

technical knowhow and labor force of tomorrow's nuclear energy industry to nations around the world. International nuclear projects represent billions of dollars in economic opportunity and each establishes up to a 100-year relationship between the supplier and host country to site, build, operate, service, and decommission the reactors. America cannot miss this economic opportunity and national security imperative.

TerraPower was founded to commercialize technologies to solve climate change and expand energy access around the world. We are proud of what we have accomplished in our thirteen years, and we look forward to continuing our work with DOE and our national laboratories to demonstrate the Traveling Wave Reactor and to continue to design and test the Molten Chloride Fast Reactor. Most importantly, we want the American advanced nuclear energy industry to succeed. We are confident in our technology but remain supportive of other entrepreneurs, scientists and engineers bringing advanced nuclear technology to market. NELA provides an immensely important opportunity to ensure that the advanced nuclear technologies we need to solve climate change and expand energy access are American technologies built and designed in the United States. NELA represents a remarkable demonstration of leadership from Chairman Murkowski, Ranking Member Manchin, and the strong group of bipartisan lawmakers who want to retain U.S. leadership in civil nuclear technology for decades to come. TerraPower offers its enthusiastic support for the Nuclear Energy Leadership Act to become law.

Sincerely,

Chris Levesque
President and CEO
TerraPower, LLC

United States Nuclear Industry Council
1317 F Street NW Washington, DC 20004

April 29, 2019

By Electronic Mail

The Honorable Lisa Murkowski Chair United States Senate Committee on Energy and Natural Resources Washington DC 20510	The Honorable Joe Manchin Ranking Member United States Senate Committee on Energy and Natural Resources Washington DC 20510

Dear Senators Murkowski and Manchin:

The U.S. Nuclear Industry Council, as the leading business consortium advocate for advanced nuclear energy and American nuclear energy exports globally, is writing to advise you of our strong and vigorous support for the Nuclear Energy Leadership Act, S. 903 (NELA) and its goal of ensuring that America is in "First Place on Nuclear Energy" to provide this vital clean energy technology in the U.S. and around the world.

In our view, NELA sends an unequivocal signal globally that the U.S. is committed to being the nuclear energy capital of the world as well as propelling its leading-edge advanced nuclear energy technology in the $3 trillion world marketplace. NELA sounds a strong bipartisan message -- particularly to Russia and China -- that America's world-class supply-chain will play a central role in providing clean, economical, reliable, flexible and passively-safe best-in-class advanced nuclear technology worldwide. From NELA's focus on bolstering the U.S. nuclear energy industrial base to accelerating early-mover deployment to cutting-edge technology to advanced fuel development to R&D infrastructure including the Versatile Test Reactor to human capital to enhanced government advocacy, the NELA charts an extraordinarily compelling and comprehensive recipe for Team USA leadership in global nuclear energy.

With 60 nuclear energy plants under construction internationally and another 100 plants on the horizon – and given nuclear energy's pivotal role in environmental progress -- it is our hope that the Senate Committee on Energy and Natural Resource, and indeed the Congress, will act with alacrity to enact NELA and its holistic prescription to buoy U.S. nuclear energy jobs, exports, clean energy leadership and national security.

The Honorable Lisa Murkowski
The Honorable Joe Manchin
April 29, 2019
Page Two

We greatly appreciate your leadership and stewardship on behalf of NELA as well the co-sponsorship of 16 other Senators to date.

Sincerely

Hon. Bud Albright
Chairman, U.S. Nuclear Industry Council
&
U.S. Under Secretary of Energy
(2006-2008)

Copy To:

Mr. David Blee, President & CEO, USNIC

USNIC Board of Directors and Members

X Energy, LLC
7701 Greenbelt Road
Suite 320
Greenbelt, MD 20770
+1 301-358-5600

April 28, 2019

The Honorable Lisa Murkowski
United States Senate
Washington, DC 20510

Dear Chairwoman Murkowski,

X Energy, LLC (X-energy), an energy solutions company developing a meltdown proof, proliferation resistant and emissions-free advanced nuclear reactor, is strongly supportive of the Nuclear Energy Leadership Act (S.903). This bill focuses on addressing the nuclear industry's technical, economic, and market challenges to enable our country to benefit from advanced reactors' clear advantages as soon as possible.

Our company is focused on creating American jobs and to rebuild American leadership in nuclear energy innovation. In 2016, X-energy was selected by the Department of Energy as one of two advanced reactor concept awardees to further develop our High Temperature Gas-Cooled Reactor (HTGR) design, NRC licensing strategies, and develop the uranium-based fuel for our reactor. We have achieved all contract milestones, are on schedule and cost, and working diligently on the technical, business and licensing issues to enable deployment of our reactor by the mid-2020s. We believe that moving forward with U.S. developed advanced reactors now is one of the most critical investments this country can make in energy in the next 30 years.

These smaller, non-light water reactors have strong potential to meet the energy needs for rural areas, islands and territories, domestic military bases and even military forward basing. There are several critical challenges to achieving market deployment of these reactors, all of which are addressed by the Nuclear Energy Leadership Act. The biggest challenge U.S. companies face in making advanced reactor implementation a reality is moving out of the Research and Development phase and into design/deployment as quickly as possible. While we support all of the provisions of the bill, key NELA bill provisions that are most impactful are:

1- Proceeding immediately with at least two demonstration (First-of-a-Kind, or FOAK) advanced reactors. We believe this is critical. Advanced reactors employ different technologies that have different levels of technical and financial maturity. To expedite deployment and gain global leadership with advanced reactors, we strongly believe that the U.S. should proceed with the ones that have the technical, regulatory, and financial capability to move forward. It is clear, based on our discussions with investors, that a FOAK reactor needs to be developed under a private-public partnership; if companies can attract the appropriate financing, we expect that the government would provide a portion of the funding to enable these demonstrations on an accelerated schedule.
2- Availability of High Assay Low Enriched Uranium (HALEU). This provision recognizes that there is currently no U.S. capability to manufacture HALEU, which is needed for most advanced reactors. It is virtually impossible to attract either investors or customers if there are no prospects for obtaining domestically produced fuel.
3- Extension of the power purchase agreements. This is a valuable financial tool in ensuring the economic feasibility of these early reactors in the near-term marketplace.

X Energy, LLC
7701 Greenbelt Road
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Greenbelt, MD 20770
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We believe that S.903 appropriately recognizes the urgency of getting these reactors into the domestic and global markets. China has just committed to 40 new nuclear power plants between 2016 and 2020, and China, Russia and several countries are moving forward with non-LWR advanced reactor technology. We expect that China's first commercial High Temperature Gas-Cooled Reactor will begin operations in 2019. The criticality of our energy security and, in fact, our national security depends on U.S. Government and Industry jointly stepping up to accelerate the development and licensing of the next generation of safer, more economical, more proliferation-resistant nuclear reactors. Failure to do so will relinquish this critical leadership role to China and Russia for decades to come.

X-energy urges the Committee to act quickly on this bill; it is vitally important. Please feel free to contact us to answer any questions, or if you would like any additional information.

Respectfully,

J. Clay Sell

J. Clay Sell
CEO, X-energy, LLC

The CHAIRMAN. Today's hearing is part of our ongoing work on nuclear policy.

Last Congress, we successfully enacted two nuclear measures, the Nuclear Energy Innovation Capabilities Act and the Nuclear Energy Innovation and Modernization Act. These provide a federal framework for the development of advanced reactor technologies.

And then through the good work of Senator Alexander and Senator Feinstein on the Energy and Water Appropriations Committee, we have provided greater funding to DOE's advanced reactor programs.

I really appreciate, Senator Alexander, your leadership in making that happen on the appropriations side. We all recognize that we can do a lot on the authorizing, but if we have not worked on the appropriating side it doesn't follow through. So your leadership there is greatly appreciated.

At a hearing earlier this year, we received testimony from Dr. Fatih Birol, who is the Executive Director of the International Energy Agency, and he spoke on the need for U.S. global nuclear leadership. After the hearing, Dr. Birol wrote to me in support of NELA. He noted his confidence that the bill will help address "many of the innovation and investment challenges that nuclear power currently faces, and boost strategic cooperation between the government, private sector and academic institutions."

So I will also include this letter for the record.

[Letter from Dr. Fatih Birol in support of S. 903 follows.]

International Energy Agency
Secure Sustainable Together

Dr. Fatih Birol
Executive Director

IEA/ExD(2019)72

Paris, 4 April 2019

The Honorable Lisa Murkowski
US Senator (R – Alaska)
22 Hart Senate Office Building
Washington DC 20510
United States

Dear Senator Murkowski,

Following on from my letter of 13 March, let me once again thank you for our meeting in Washington on 28 February. It was a great honour for me, and for the IEA, to testify in front of the US Senate Committee on Energy and Natural Resources under your very capable Chairmanship.

I am writing to you now to congratulate you for introducing the Nuclear Energy Leadership Act (NELA). As you know from my senate testimony, I share the view that nuclear power has a very important role to play in a clean and secure energy system. The United States has been a leader in nuclear power generation technology for 60 years. Nuclear still generates twice as much low-carbon electricity in the United States as wind and solar combined. The baseload capacity of nuclear power plants also plays a major role in maintaining electricity security.

But nuclear is facing major challenges. Without effective policy action your country will be on track to lose a substantial proportion of its capacity. From my vantage point, this would be detrimental to both energy security and clean energy objectives. In order to safeguard the long-term contribution of nuclear, the United States also needs to continue to accelerate innovation in new nuclear technologies. In addition, measures are also needed to safeguard the existing fleet by extending lifetimes as long as safety considerations allow.

I am confident that the provisions you have included in the NELA will be successful in addressing many of the innovation and investment challenges nuclear power currently faces, and boost strategic co-operation between the government, private sector and academic institutions. This would allow the United States to not only continue to have a strong domestic nuclear power industry but also remain an international leader in the civil nuclear marketplace.

I wish you every success with this important initiative, and I stand ready with my staff to provide any input and support in the process that you may require.

Yours sincerely,

F. Birol

Dr. Fatih Birol

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Website: www.iea.org

The CHAIRMAN. I am particularly excited about a subcategory of advanced reactors that we call the microreactors, which have off-grid capability and could help provide clean, affordable energy in many of our remote towns and villages.

Alaskans certainly recognize the potential of this technology. The University of Alaska held a stakeholder's meeting with nuclear experts in Anchorage just a couple weeks ago, and then our State Senate held a hearing on microreactors during their legislative session in Juneau just last week.

As we pursue the future of nuclear energy, it is also important that we contend with the Federal Government's failure to meet its obligations for spent nuclear fuel. Solving that nuclear waste stalemate is a top priority of mine, again working with Senator Alexander and Senator Feinstein on this, but that is one of the reasons why Senators Alexander, Feinstein and myself are introducing today the Nuclear Waste Administration Act. Again, we look at how we can advance the nuclear opportunities that we have in this country, but if we haven't been able to deal with the waste side of it, we know that it is going to continue to be a struggle. So I look forward to working on that.

Before I introduce the distinguished panel that we have in front of us today, I would like to turn to Senator Manchin for his opening remarks and then we will do introductions here.

Senator Manchin.

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

Senator MANCHIN. Thank you, Chairwoman Murkowski, and thank you for having this hearing on advanced nuclear technology development, and I want to thank all of our witnesses for being here today who will provide us with a comprehensive picture of what is needed to ensure that the U.S. is leading the nuclear technology race.

In particular, I would like to thank Mr. McManus, who will provide us with the union workforce point of view, a valuable part of this conversation today.

Over the past few months, I have met with several advanced energy industry innovators, including Bill Gates. Mr. Gates' investment in pursuing advanced nuclear to meet global energy needs is a reflection of the enormous potential that nuclear power can contribute to our energy future. The private sector has already spent about $1.3 billion on advanced reactor technology.

I believe that the Federal Government must lead with the private sector, so I am very encouraged by this hearing today.

Even though we don't have nuclear power in West Virginia, I am very proud to be a cosponsor of the bipartisan Nuclear Energy Leadership Act, NELA, which currently has 17 Senate cosponsors. The bipartisanship behind this bill demonstrates our shared values about energy policy. NELA provides a pragmatic pathway to finally build advanced nuclear demonstration projects, which is a critical step toward commercialization that we often struggle with.

Nuclear power has provided nearly 20 percent of electricity generation in the U.S. over the past few decades and currently represents about 60 percent of America's carbon-free electricity.

The U.S. had been a leader in nuclear, but in the past 20 years our hold on that position has been slipping. Advanced nuclear commercialization could really change that.

This technology holds the potential to advance other vital policy objectives in our nation's interest, including non-proliferation and national security, nuclear safety, energy security and economic growth and by maintaining our nuclear supply chain we can create and maintain high paying manufacturing jobs in the U.S. However, to ensure that nuclear energy continues to be a viable option, the Department of Energy, the national laboratories, universities, unions and private industry must all work together.

The Department of Energy and our national laboratories play a central role in leading this effort. If the U.S. wants to lead in the global transition to a low-carbon economy, advanced nuclear is perhaps the key for leading beyond the electric sector and in the heavy industry sector.

A big part of the carbon conversation that requires more attention is the manufacturing sector. Process heat for manufacturing chemicals, forest products, iron and steel, cement, plastics and rubber products and many other crucial products is a major producer of carbon emissions. These products require temperatures in the range of 100 degrees Celsius to as high as 900 degrees Celsius. Some of these temperatures can be reached using today's light water reactor technology, but if we are serious about decarbonizing our manufacturing sector, advanced nuclear technologies will be needed for higher temperature manufacturing.

Advanced nuclear demonstration projects represent an extremely promising opportunity to bring together several sectors of the economy to see how nuclear power manufacturing technologies can all work together because if we are successful in commercializing this technology and bringing it to market first, we will be creating jobs right here in the United States.

I know the unions can attest to the fact that the U.S. must have the best trained workers in the world, the most advanced technology and a superior research, development and demonstration nexus in order to maintain manufacturing jobs domestically. And as we move forward, we will constantly need to be in the lead to maintain jobs here in the United States.

I am glad that we have union representation on this panel today to speak for the working person also. The skilled workers that Mark McManus represents are the ones that are actually going to be building the technologies we are talking about today. If we didn't have the most skilled workers in the world, we wouldn't even be having this conversation right now. And I think it is important that we spend some of this hearing talking about the importance of workforce training in growing manufacturing jobs here. Maintaining a skilled workforce is also a key to maintaining a current nuclear fleet. A single nuclear plant represents as many as 3,500 jobs.

While today's hearing is focused on advanced reactors, we must also recognize the importance of investing in R&D funding in our existing nuclear fleet in order to improve the operations of these plants and maintain reliability throughout our electric sector. For if successful in our advanced nuclear efforts, we will lead the way in revolutionizing the large parts of the global economy.

Countries will look to the U.S. for the best materials, technology and expertise. That means greater economic security and more high paying jobs. We face enormous challenges, but there are enormous opportunities here too.

Once again, I would like to thank Chairman Murkowski for holding this incredibly important hearing. I look forward to further discussing these topics with each one of you today.

Thank you, Madam Chairman.

The CHAIRMAN. Thank you, Senator Manchin.

And thanks to our witnesses for being with us. I think we are going to have a good discussion this morning, and I look forward to your contributions.

I will begin with introductions. Dr. Peters, I am going to skip over you. We are going to allow my friend and colleague, Mr. Risch, to introduce you.

But we are joined this morning by Dr. Ashley Finan, who is the Director of the Nuclear Innovation Alliance (NIA). It is good to have you here.

Maria Korsnick is with us this morning, friend and strong fisherwoman, the CEO of the Nuclear Energy Institute (NEI), and we appreciate your contributions here this morning.

Mr. McManus has just been spoken to by my friend here this morning. Why am I drawing a blank on your name, Senator Manchin?

[Laughter.]

Senator MANCHIN. It happens all the time.

The CHAIRMAN. It is our Monday around here.

Mr. McManus, as was indicated, is the President of the United Association of Journeymen and Apprentices of the United States and Canada. We do welcome your perspective this morning on behalf of labor. Thank you.

We are also joined by the Honorable Jeffrey Merrifield, who previously served as a Commissioner on the Nuclear Regulatory Commission (NRC). He is joining us today as Partner and Energy Section Leader at Pillsbury, Winthrop, Shaw and Pitman. We are pleased to have you here.

Senator Risch, I would invite you to introduce our first witness here, Dr. Peters.

STATEMENT OF HON. JAMES E. RISCH, U.S. SENATOR FROM IDAHO

Senator RISCH. Thank you.

Thank you, Madam Chairman, and thank you for holding this important hearing regarding the U.S. global leadership in nuclear energy and the Nuclear Energy Leadership Act.

Senator Manchin mentioned having met with Bill Gates. I think most of us on this Committee have. I think we all recognize Bill Gates is a real visionary. What he and his wife, Melinda, have done to, essentially, eliminate polio on the planet is nothing short of miraculous. He truly is a visionary. One of his visions involves bringing electricity to the billion people in the world, the ones that do not have it. He is exploring that and doing it the way he always does it, in a very commonsense, rational sort of way. He has some ideas, and I am sure you found it fun to bounce ideas around with him. It is important that as we talk about the U.S. global leadership on this issue that he be included in that.

It is very appropriate that we have Dr. Peters with us here today. Dr. Peters, in recent years, has led the Idaho National Laboratory (INL). And when we are talking about world and global leadership in nuclear energy, it is really appropriate that the Idaho National Laboratory and its leader be here.

Idaho is where it all started. The place where Dr. Peters' offices and his laboratory are is where the first electricity was generated with nuclear power. We still have the first three light bulbs that were lit by nuclear power in the history of the world. So when it comes to U.S. leadership, that is very important to us in Idaho.

It has been a privilege working with Dr. Peters over these recent years. The Department of Energy has given the lab management performance grades of A in all recent years. And while Dr. Peters has been in charge of the lab, he also exploited the Idaho State Board of Education's buying authority to build two new buildings which is, kind of, a view for us for the future, the first having to do with cybersecurity and the second having to do with advanced computing which we believe the Idaho National Laboratory is well poised to lead in these areas also.

In 2017 the INL restarted the TREAT reactor, and this reactor was restarted ahead of schedule and under budget. Congratulations, Dr. Peters.

Dr. Peters serves as a Senior Advisor to Department of Energy on nuclear energy technologies and research and development programs and on nuclear waste policy which has been very important to us in Idaho over the years. With that, again, I want to underscore the fact that Dr. Peters is the right witness to have at this hearing.

Thank you, Dr. Peters, for being here. Thank you to all of the witnesses.

Madam Chair.

The CHAIRMAN. Thank you, Senator Risch.

Having had the opportunity to go out and visit Idaho National Lab at your invitation and of our leaders there at our national labs, it is a trip that is well worth taking and really helps put into context all that we are dealing with, but all the innovation and just, really, the expertise that goes on. So thank you for that introduction.

With that, Dr. Peters, why don't you begin?

I would ask each of you to try to limit your comments to about five minutes. Your full statements will be included as part of the record, but we would like to begin the back and forth that we will be able to do once you have concluded your introductory statements.

Dr. Peters, welcome.

STATEMENT OF DR. MARK PETERS, LABORATORY DIRECTOR, IDAHO NATIONAL LABORATORY

Dr. PETERS. Thank you. Good morning.

Thank you, Senator Risch, for the kind introduction and all you do, your outstanding leadership, appreciate it very much.

Chairwoman Murkowski, Ranking Member Manchin and members of the Committee, it's an honor and privilege to be with you here today. My name is Mark Peters, and I'm the Director of Idaho National Laboratory, or INL. I'm grateful for the opportunity to testify today on the Nuclear Energy Leadership Act, as you've already heard, better known as NELA. And I wanted to thank the bipartisan coalition that has sponsored this bill, many of whom are represented on this Committee and that also includes Senators Risch and Crapo from my home State of Idaho.

I have submitted testimony for the record, and I will summarize it briefly here.

The United States has for decades amassed an unsurpassed record of nuclear reactor safety, security, efficiency, reliability, resiliency, and powers nearly one-fifth of our nation's electricity system. It also produces, by far, America's largest percentage of low-carbon electricity. Nuclear energy is one of the most effective tools we have to combat the effects of climate change. Moreover, a strong nuclear energy industry is an important component in ensuring U.S. national security and stabilizes the U.S. power grid and is a major driver of the U.S. economy.

In alignment with the goals of NELA, INL, in partnership with our national laboratories and universities, is working with the private sector to develop, demonstrate and ultimately deploy the next generation of nuclear reactors. The innovative design of small modular reactors promises to enhance safety, reduce cost and increase adaptability with renewable energy in our future energy system.

Construction on the world's first small modular reactor could begin at the INL site in 2023. The new scale power reactor could begin producing electricity for the Utah Associated Municipal Power Systems utility in 2027.

Meanwhile, some utilities and the U.S. Department of Defense are thinking even smaller. These 2- to 20-megawatt microreactors could provide electricity for military bases and remote communities among other applications. We are on track at INL to develop and demonstrate, in partnership with the Federal Government and private sector, a microreactor within the next five years.

Recently, as you are well aware, Congress passed and the President passed into law two groundbreaking pieces of legislation relevant to nuclear energy.

The Nuclear Energy Innovation and Modernization Act provides the regulatory framework needed to develop advanced reactors. The Nuclear Energy Innovation Capabilities Act, or NEICA, defines a science and innovation agenda and, among other things, calls for establishment of a National Reactor Innovation Center to support advanced reactor development and demonstration which we see centered at Idaho National Laboratory.

NELA is the third leg of this stool and we strongly support the goals of this important legislation, and I want to summarize why.

First, NELA calls for completion of two advanced nuclear reactor demonstration projects by the end of 2025 and from two to five additional operational advanced reactor designs by the end of 2035. We applaud those goals, recognizing they are aggressive because they will drive the necessary prioritization and strong sense of urgency that we must have. We do need to have a robust and transparent process with strong input and guidance from the private sector as we select the technologies and designs to be demonstrated, accounting for factors such as economics, technology maturity, potential markets and many other factors.

Second, NELA, along with NEICA, includes authorization of a versatile, reactor-based fast neutron source, or what we call the Versatile Test Reactor, to support testing advanced fuels, materials, instrumentation and sensors. Consistent with NEICA, U.S. DOE has approved a Critical Decision 0 (CD-0) for the Versatile Test Reactor identifying the mission need and initiating work on conceptual design, management plans and further refined cost and schedule estimates.

Third, NELA allows the Federal Government to partner with industry and demonstrate and deploy new nuclear energy technologies by authorizing long-term power purchase agreements.

Fourth, NELA addresses a fuel supply issue that threatens to limit deployment of advanced reactors, that is, the need for high-assay, low-enriched uranium, better known as HALEU.

Finally, NELA seeks to ensure that a highly skilled world-class workforce is available to enable the next generation of nuclear reactors. The universities are vital to this and the nation's broader nuclear energy mission.

So in summary, as the nation's nuclear energy laboratory, INL feels a special responsibility to enable a nuclear energy future and move forward urgently to demonstrate advanced reactor technologies.

I am optimistic we will succeed because of the innovation coming out of our labs, universities and the private sector. I am also optimistic because of the bipartisan support that we see for nuclear energy here in Washington and in states across the nation. And I am optimistic because the historic partnership between government and industry has laid the foundation for our success. We have done this before.

Thank you for your attention to this important issue, and I look forward to answering your questions.

[The prepared statement of Dr. Peters follows:]

TESTIMONY OF
DR. MARK PETERS, LABORATORY DIRECTOR
IDAHO NATIONAL LABORATORY
BEFORE THE
U.S. SENATE COMMITTEE ON ENERGY & NATURAL RESOURCES
"Full Committee hearing on U.S. Leadership in Nuclear Energy and to Receive Testimony on NELA."
APRIL 30, 2019

Chairwoman Murkowski, Ranking Member Manchin, and members of the committee, it is an honor and privilege to be with you today. My name is Mark Peters, and I am the director of Idaho National Laboratory. I'm grateful for the opportunity to testify on S. 903, the Nuclear Energy Leadership Act (NELA). I want to thank the bipartisan coalition that sponsored this bill, including the senators from my home state, Senators Risch and Crapo. It is gratifying to see Members of Congress from both parties acknowledging, through NELA and two other pieces of legislation passed and signed into law within the last year, nuclear energy's significant contributions to American prosperity and security.

The United States has for decades amassed an unsurpassed record of nuclear reactor safety, security, reliability, resiliency, and efficiency. Nuclear energy powers nearly one-fifth of our nation's homes, hospitals, schools, and businesses. It also produces, by far, America's largest percentage of zero-carbon electricity, 56.1 percent, more than hydro, wind, solar, and geothermal combined.

America's 98 nuclear power plants prevent the release of nearly 550 million tons of carbon dioxide into the atmosphere every year. That's the equivalent of taking 117 million passenger cars off the road. As the only carbon-free, scalable energy source that produces electricity 24-7-365, nuclear energy is one of the most effective tools we have to combat climate change, in the U.S. and across the world. Because of the growing concerns about climate change, groups historically skeptical of nuclear energy are beginning to think differently, including the Union of Concerned Scientists and Nature Conservancy, to name two.

In the 1960s, the U.S. emerged as the leader in global nuclear reactor development and commercialization, laying the groundwork for the commercial nuclear industry. Because of that, the vast majority of reactors around the world are based on American technology. Our safety and nonproliferation approaches are the world's standards. As a result, a strong nuclear energy industry is an important component in ensuring U.S. national security.

Nuclear energy stabilizes the U.S. power grid by producing reliable and affordable electricity under even the worst weather conditions. When hurricanes hit Texas and Florida, nuclear power plants provided electricity to customers in their time of need. When the Midwest and East Coast experienced polar vortexes, nuclear energy heated homes and businesses.

Finally, nuclear energy is a major driver of the U.S. economy, contributing $60 billion annually to the nation's gross domestic product and supporting more than 100,000 direct jobs.

Over the last three decades, however, our nuclear energy leadership role has been allowed to atrophy. A variety of factors – high capital costs, the long time frame of licensing and construction, subsidies for other forms of electricity generation, the low cost of natural gas, and our inability to deal with waste and used fuel – has led to premature nuclear plant closures and abandonment of new projects.

We remain among the world leaders, but our advantage is shrinking. In the worldwide energy race, our competitors, specifically China and Russia, are rapidly making up ground. When the U.S. domestic nuclear energy industry languishes, our export ability and international leadership role is adversely affected. That provides openings for our competition. According to the Nuclear Energy Institute, Russia has orders valued at more than $300 billion for 34 nuclear power plants in 13 countries. Russia also holds the largest share of the multibillion-dollar global market for uranium fuel enrichment services once dominated by the U.S. The Russian government is pursuing an aggressive nuclear export strategy because it understands the long-term influence that results from building a nuclear power plant in another country.

Nor should we cede world leadership to China. The Chinese government understands nuclear energy can help power its own country and mitigate its pollution problems. China also sees an opportunity to increase its influence across the world while reducing ours.

The state-sponsored nuclear energy industries in Russia and China represent a serious challenge to our historic leadership in this vital arena. But we have a tremendous tool at our disposal: bold entrepreneurs across the private sector working collaboratively with the best minds at our universities and national laboratory system to design, develop, demonstrate, and deploy advanced reactors. As the nation's nuclear energy research and development laboratory, Idaho National Laboratory plays a major role in the effort to make sure America remains a world leader in nuclear energy research, development and deployment. On our 890-square-mile Site, the U.S. government and private sector built, tested, and demonstrated first-of-a-kind reactors that were later deployed around the world.

A core mission of the DOE Office of Nuclear Energy is to maintain and extend the lives of the nation's high-performing nuclear reactor fleet. Laboratories within the DOE complex, including INL, support this core mission. INL is working with utilities to modernize control rooms, and provide support in the license renewal process. Licensing, however, is but part of the equation. Understanding the economic challenges confronting the nuclear energy industry, DOE's Light Water Reactor Sustainability (LWRS) program, which is led by INL, also is collaborating with the private sector to help utilities reduce operating costs.

In alignment with the goals of NELA, INL also is working with the private sector to develop, demonstrate, and deploy the next generation of nuclear reactors. More than 50 advanced nuclear companies across North America are examining a number of advanced reactor concepts, often in partnership with INL and other DOE national laboratories. Among other things, they are looking at:

- How to make reactors smaller and modular – small enough even to be mass-produced in factories.
- How to use coolants other than light water.
- How to operate at normal atmospheric pressure.
- How to use physics in addition to engineering to keep reactors safe.
- Some designs can even use recycled nuclear waste as fuel.

Private sector innovation and partnerships with the public sector, national laboratories, and universities is driving the future of nuclear energy. Look at the UAMPS/NuScale project, for example. The Utah Associated Municipal Power Systems is a consortium that provides electricity to more than 40 cities in six Western states. The centerpiece of its Carbon Free Power Project is a small modular reactor designed by Oregon-based NuScale Power. INL has been involved with NuScale from the beginning, providing technical support and guidance. Construction on the world's first small modular nuclear reactor could begin at the INL Site in 2023. The NuScale Power reactor, consisting of 12 60-megawatt modules, could begin producing electricity for UAMPS in 2027.

The innovative design of these small, modular reactors promises to enhance safety, reduce costs, and increase adaptability with renewables such as wind and solar. And, as part of an agreement between UAMPS and DOE, one module will be used for research at INL. A second will be used to provide electricity to the INL Site.

But some utilities – and the U.S. Department of Defense – are thinking even smaller. Westinghouse, NuScale, General Atomics, Oklo, X-energy, and others are working on microreactor designs. These 2- to 20-megawatt reactors could provide electricity for military bases and remote communities that run their electrical grids on imported diesel. Microreactors also are a good option for off-grid industrial and mining operations, and large energy consumers in developing nations. Quoting from Senator Murkowski's recent op-ed: "Microreactors could provide the energy necessary to run a mine, an oilfield, or any number of projects – again at a far lower cost and no emissions, with less land usage and a simpler permitting process." Finally, think of microreactors in islanded microgrids that allow Puerto Rico to continue producing electricity after a hurricane, or to be safely shipped to areas recovering from devastating storms and natural disasters.

Microreactors could be built in a factory and transported. They are a clean power source designed to serve a range of energy applications. Best of all, we are on track to develop and demonstrate, in partnership with the federal government and private sector, a microreactor at INL within the next five years.

Next generation reactors will not be entirely focused on electricity production. Process heat, steam, or other thermal transport/media from nuclear reactors have the potential to revolutionize our transportation systems and manufacturing processes. We can produce hydrogen for use in vehicles and industry, and electrify significant portions of the transportation sector. We can make great strides in desalination and water purification, chemical processing, metal and glass refining, biomass, and much more.

We can only do all this after we develop and demonstrate new technologies. The Nuclear Energy Innovation Capabilities Act (NEICA), passed by Congress last year and signed into law by President Trump, will help us do that. NEICA calls for establishment of a National Reactor Innovation Center (NRIC) to support advanced reactor development and demonstration. In many ways, this approach harkens back to the decision in 1949 to establish the National Reactor Testing Station at what is now INL. Our predecessors built and operated 52 original test reactors, laying the foundation for a U.S. commercial nuclear energy industry that has helped drive American prosperity and ensure national security.

We see the NRIC as a place where government and private companies can come to INL to develop, test, and demonstrate new reactor designs, as well as materials, fuels, and other nuclear energy technologies. The NRIC at INL will include:

- Sites for testing and demonstration of new and novel reactors;
- Facilities that support research and development of advanced materials and fuels through unique R&D facilities for fuel fabrication, irradiation, and characterization;
- Integration of high-performance computing capabilities with experimental capabilities to create a new digital engineering approach to nuclear reactor development; and
- Laboratory, industry, and university partnerships to support the future workforce through training and education.

But if we're going to deploy advanced reactors, we need to build one. We need to get started. Given the advances made by Russia and China, we need to act with urgency. The race is being run and our competitors are strategic and aggressive. That sense of urgency is evident in the approach taken by Congress and the Trump Administration. In just the past year, with broad bipartisan support, Congress passed and the president signed into law, two groundbreaking pieces of legislation: the aforementioned NEICA and the Nuclear Energy Innovation and Modernization Act (NEIMA), which will provide the regulatory framework needed to develop advanced nuclear reactors capable of powering our homes and businesses, transportation systems, and manufacturing processes. Thanks to everyone involved in passage of those bills, because they were important steps in reducing technical and regulatory barriers to development of the advanced reactors that will allow us to meet growing energy demands while mitigating the effects of climate change.

NELA is the third leg of this stool. Here's why I say that:

1) NELA sets aggressive goals for advanced nuclear reactor research, development, and demonstration.

   NELA calls for completion of two advanced nuclear reactor demonstration projects by the end of 2025, and from two to five additional operational advanced reactor designs by Dec. 31, 2035. We applaud those goals, recognizing they are aggressive, because they will drive the necessary prioritization and sense of urgency. We do need to have a robust and inclusive process for selection of technologies and designs that accounts for economics, technology maturity, potential markets, and other factors. This will need to be guided thoughtfully by the government, with strong input and guidance from the private sector. The nation's nuclear energy research and development laboratory – and our partner national laboratories – are prepared to help the nation achieve those goals.

   Moreover, all of this requires robust federal support for science and innovation, and we are eager to work with our colleagues across the national laboratory system to implement Senator Alexander's New Manhattan Project for Clean Energy Independence. Finally, we appreciate Senator Manchin's effort to facilitate commercialization of R&D technologies from the national laboratories, another key enabler for future advanced reactors.

2) NELA, along with NEICA, offers to the national laboratories tools they will need to help the private sector develop, demonstrate, and deploy advanced reactors.

   That includes authorization of a versatile, reactor-based fast neutron source or Versatile Test Reactor (VTR). A fast neutron test reactor is needed to support testing of advanced fuels, materials, instrumentation, and sensors. Importantly, this is a capability the U.S. does not possess. Development and construction of this fast test reactor will eliminate reliance on Russia for these irradiation tests and reposition the U.S. at the forefront of developing and improving new nuclear energy systems.

   A VTR will be available to U.S. companies, national laboratories, and universities for testing of advanced fuels, materials, instrumentation, and sensors. This capability will play a critical role in helping develop advanced fast reactors that generate as much as 10 times the power of existing reactors, use less water, and produce waste that is easier to handle and which remains highly radioactive for a shorter period of time.

   Consistent with NEICA, the Department of Energy has approved a Critical Decision 0 (CD-0) for the VTR, identifying the mission need and initiating work on R&D, prototyping, conceptual designs, management plans, and cost and schedule estimates.

3) NELA allows the federal government to partner with industry and demonstrate new nuclear energy technologies.

   Earlier, I referenced DOE purchasing power from UAMPS. The Joint Use Modular Plant (JUMP) program is essential to the completion of UAMPS' Carbon Free Power Project. By authorizing long-term power purchase agreements – and establishing a long-term nuclear power purchase agreement pilot program – NELA offers significant, potential assistance to demonstrate and deploy advanced reactors.

4) NELA addresses a fuel supply issue that threatens to limit deployment of advanced reactors.

   The availability of high-assay, low-enriched uranium (HALEU) is an important factor in determining the future of the advanced nuclear energy industry. Many advanced reactors will require HALEU to operate. A commercially available supply is absolutely necessary if the U.S. wants to lead the world in development and deployment of advanced reactors.

   NELA addresses this challenge in two important ways: by establishing a program to provide a minimum amount of advanced reactor fuel until a long-term domestic supply is developed; and by facilitating development of HALEU-appropriate transportation equipment. Options for near-term supply being evaluated by DOE, the national laboratories, and the private sector include reestablishing domestic enrichment, accelerating processing and treatment of EBR II spent fuel, and processing and treatment of Highly Enriched Uranium (HEU) fuels.

5) NELA takes the long view, and seeks to ensure that a highly skilled, world-class workforce is available to develop, deploy, regulate, and safeguard the next generation of nuclear reactors.

   America's 98 nuclear power plants provide community-sustaining careers. The plants of the future, featuring as NELA requires, "a diversity in designs," have the potential to provide hundreds of thousands of Americans jobs that pay well above the median salary, provide excellent benefits, and allow their employees the satisfaction of knowing they are serving their communities and nation.

   The UAMPS SMR project in Idaho is an excellent example of the economic and social benefits that come with advanced reactor projects. Plant construction will create more than 1,000 jobs during the three-year peak. Upon completion, the NuScale plant will support roughly 300 jobs with an average salary of $85,000. For perspective … the median household income in Idaho is $48,275.

   We need to accelerate the process of training our young people for the jobs of the future. The University Nuclear Leadership Program envisioned by NELA is a positive step forward in meeting future workforce needs.

   In summary, as the nation's nuclear energy laboratory, INL feels a special responsibility to help reverse the trend of the last three decades. We have ceded ground to Russia and China, but the race is not over. We are at a critical juncture, a turning point. Decisions made today will determine if the U.S. continues to lead the world in nuclear energy innovation and production, or if we are destined to fall back into the pack.

Still, I remain optimistic.

I remain optimistic because of the daily innovations coming out of our national laboratories, universities, and private sector. We have the finest facilities, most developed capabilities, and best minds.

I remain optimistic because of the bipartisan support for nuclear energy in Washington, D.C., and in statehouses across the nation. A growing number of policymakers from across the political spectrum are recognizing nuclear energy's importance to our power grid, economy, environment, and national security.

I remain optimistic because of our history. America has an historic role in inventing many energy technologies in use around the world, from the lightbulb to the nuclear reactor.

And, I remain optimistic because the historic partnership between government and industry has laid the foundation for our successes. We know what it will take because we have done it before.

NEICA and NEMA were important steps in the effort to make sure the U.S. is a world leader in advanced reactor research, development, licensing, and deployment. NELA will help us complete that journey, and ensure that our nation can meet future energy demands, combat climate change, ensure national security, grid reliability and safe operations, and jump-start our economy.

Thank you for your attention to this important issue. I look forward to your questions.

The CHAIRMAN. Dr. Peters, thank you very much.

Dr. Finan, welcome to the Committee.

STATEMENT OF DR. ASHLEY E. FINAN, EXECUTIVE DIRECTOR, NUCLEAR INNOVATION ALLIANCE

Dr. FINAN. Thank you.

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 be here today. My name is Ashley Finan, and I'm Executive Director of the Nuclear Innovation Alliance. The NIA is a non-profit think tank dedicated to supporting entrepreneurialism, accelerated innovation and commercialization of advanced nuclear energy to address global energy needs.

In the United States and elsewhere dozens of innovative companies are pioneering advanced nuclear designs but take advantage of decades of technological progress and experience. Innovators are focusing on better meeting the needs of traditional markets through reduced costs as well as meeting the needs of new markets, including microgrids that power remote communities, secure power for critical infrastructure and grids with high penetration of renewable 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 lost leadership in nuclear energy. U.S. nuclear energy leadership is important for geopolitical and environmental reasons. It can be restored, and the Nuclear Energy Leadership Act would help make that possible. My written testimony covers these topics in greater detail.

Scholars predict we'll see major changes in energy geopolitics as we move toward a decarbonized energy system. Nuclear energy will have strategic import partly because it compels technological dependence that is more enduring than that of oil or gas. Nuclear plants in Hungary, Slovakia, Bulgaria and the Czech Republic that have lifetimes of 40 to 80 years can only be fueled by a single Russian company.

Some figures comparing nuclear to oil and gas markets are illustrative. Eighteen countries account for 90 percent global oil and gas supply with Saudi Arabia supplying 19 percent of internationally-traded crude oil and Russia supplying 20 percent of gas as of 2016. By comparison, just six countries account for 90 percent of nuclear technology supply, and Russia is the supplier in 46 percent of nuclear technology agreements while the U.S. is a supplier in 10 percent.

Past participation in nuclear markets gave the U.S. leverage in influencing global non-proliferation safety and security norms. If we are not a major supplier, we cede that influence.

Last Wednesday the Nigerian Minister of Defense asked Russia to help Nigeria build pipelines, railways and nuclear power plants. This is just one example of what seems like weekly news of Russia's prominence.

Russia and China are thinking and acting strategically. They have the capacity and the will to bundle generous financing with nuclear deals. Where the United States excels is in innovation. We have the best innovators, labs and private investors. Moving that innovation to commercialization provides us with an opportunity to compete if we complement it with supportive policy.

As a non-emitting energy source, nuclear energy delivers cleaner, healthier air. To mitigate the consequences of climate change, we need to decarbonize global economies. Studies show that the most affordable pathways to deep decarbonization consistently include firm, low-carbon resources like nuclear energy and that our odds of success improve with a balanced portfolio that includes nuclear.

We also know that nuclear can scale quickly. Based on nuclear energy, France achieved 80 percent electricity decarbonization in under two decades.

Many are doubtful about our ability to develop the technology fast enough, but history counsels us to be more hopeful. We have not done this recently, but we have done this before.

The Electric Power Research Institute found that the two types of reactors we operate here in the U.S. were fully commercialized in 15 years and 13 years, respectively. Working with private industry, the Atomic Energy Commission demonstrated about a dozen plants in as many years covering eight technologies for $4.3 billion, including 66 percent industry cost share. But we've learned a lot since then, and we can more effectively harness the power of the market on the private sector.

A forthcoming report from my organization will suggest specific improvement approaches that would use insights from the NASA Commercial Orbital Transportation Services program, the program that helped elevate SpaceX to its current notoriety.

The United States should redouble efforts to commercialize scalable, affordable and unparalleled nuclear power. We see the private sector pursuing bold ideas and they need government to join and support them with the spirit of the Atoms for Peace era but with the benefit of decades of advancement in technology and policy.

NELA could do just that. NELA's goals are specific, measurable, ambitious and if they are coupled with private sector action and complementary policies, NELA's goals are achievable. The NIA supports the Nuclear Energy Leadership Act and applauds its cosponsors for their initiative and commitment.

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

[The prepared statement of Dr. Finan follows:]

Dr. Ashley E. Finan
Executive Director
Nuclear Innovation Alliance

Testimony for the Record
Dr. Ashley E. Finan, Executive Director
Nuclear Innovation Alliance

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
April 30, 2019

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=dMeO_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

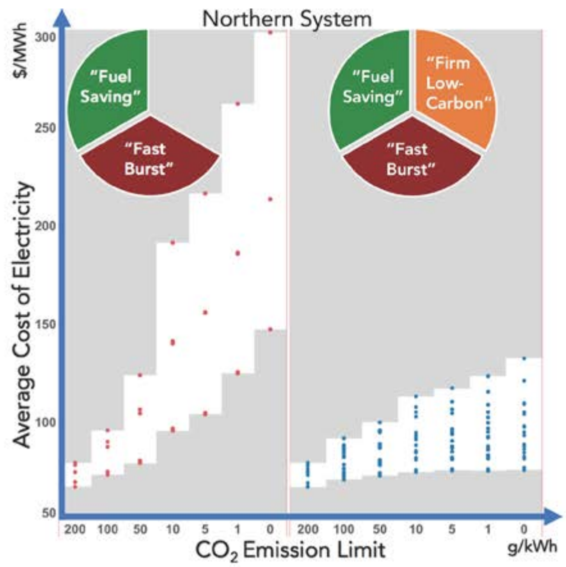

Figure 1: Average Cost of Electricity under Various Technology Assumptions and CO_2 Emission Limits for the Northern System (a) with a decarbonization policy that ex-ante excludes firm low-carbon resources on the left and (b) with a decarbonization policy that includes firm low-carbon resources on the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

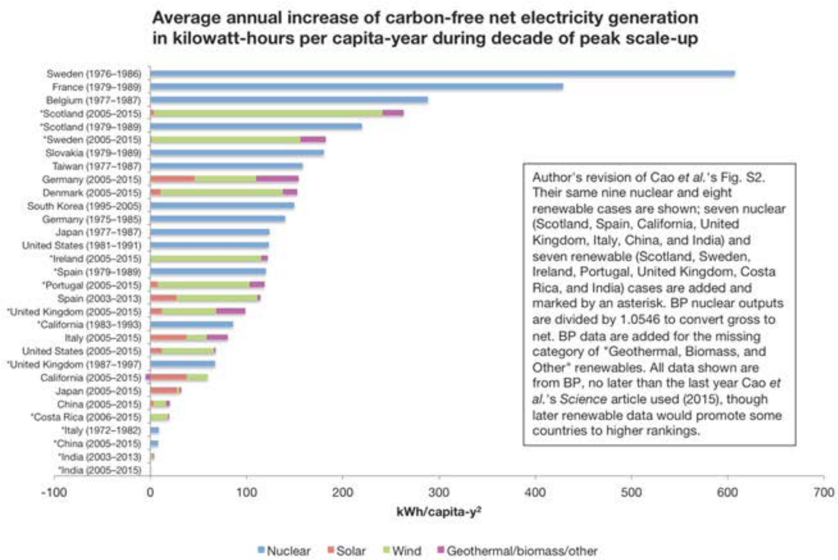

Figure 2: Average annual increase of carbon-free net electricity generation in kilowatt-hours per capita-year during decade of peak scale-up.

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

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[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

[37] See for example: Abdulla A, Ford MJ, Morgan MG, Victor, D. (2017) "A retrospective analysis of funding andfocus 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 ofU.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.

The CHAIRMAN. Thank you, Dr. Finan. I apologize for mispronouncing your name several times here this morning.

[Laughter.]

We will look forward to the specific——

Senator MANCHIN. At least you didn't forget it.

The CHAIRMAN. Yes, at least I didn't forget it, thank you, Senator Manchin.

[Laughter.]

We will look forward to those specific recommendations coming out of that report.

My friend here—Ms. Korsnick, welcome to the Committee.

STATEMENT OF MARIA KORSNICK, PRESIDENT AND CEO, NUCLEAR ENERGY INSTITUTE

Ms. KORSNICK. Great, thank you.

Thank you, Chairman Murkowski, Ranking Member Manchin and members of the Committee. Thank you for the opportunity to appear before you today.

I'm Maria Korsnick, President and CEO of the Nuclear Energy Institute with 33 years in commercial nuclear experience.

I thank you for the continuing focus on nuclear energy and specifically, today, the next generation of nuclear, carbon-free power in America. I sincerely appreciate the overwhelming bipartisan support that we saw last Congress for the Nuclear Energy Innovation Capabilities Act as well as the Nuclear Energy Innovation and Modernization Act. Both of these will help ensure the United States remains a global leader of nuclear innovation.

America's nuclear industry is at a crossroads. We urgently need tangible actions from Congress that it values nuclear, carbon-free power. This is not a partisan issue. Republicans and Democrats recognize that nuclear energy is a critical national asset to provide clean, reliable and affordable electricity to Americans. And yet, right now 12 nuclear reactors are slated for premature closure nationwide. If that happens, it will take offline enough electricity to power 8.6 million homes. That's almost as many homes as in all of Alaska, West Virginia, Tennessee and Michigan and a massive quantity of clean, carbon-free energy. And remember, once a nuclear plant is shut down it can't be put back online. It's lost for good.

Now is the time to preserve the existing fleet. Extend a plant's life span to 80 years through second license renewal applications and grow our nuclear energy fleet through new build. When America leads, we help set the global standards for safety, for preventing proliferation and we create hundreds of thousands of American jobs.

But the fact is today we are ceding our global leadership in a technology that we invented. Right now, 55 reactors are under construction nationwide, excuse me, worldwide. Nearly two out of every three reactors are being built by either Russia or China. Failure to lead the next wave of global nuclear construction means significantly diminished ability to promote U.S. safety standards, operational excellence, non-proliferation and security norms around the world. Simply put, U.S. influence grows when we have a strong, civil nuclear industry.

The Committee gets that. You understand that while the fleet of today is America's emission-free workhorse, the reactors of tomorrow will be even safer and more innovative. But to get there, we need help and help of this Committee. The bipartisan Nuclear Energy Leadership Act is a great start. NELA does many things. I'll focus on just a few.

First, it authorizes the funding of nuclear reactor demonstration projects. The United States simply must build. Over the last three decades of the 20th century, the U.S. built 113 commercial reactors. In the 20 years following those builds, we are on pace to complete only three more, one recently brought on in Tennessee and two nearing completion in Georgia. There are dozens of U.S. companies developing designs to meet the anticipated market needs. This is great news. But if we want to lead the world in nuclear technology, we need to build plants. The demonstrations authorized in NELA will be the catalyst to construct advanced reactor designs that the United States, not Russia, nor China, can offer the world to address climate change.

Second, the bill calls for the Federal Government to establish a pilot program to enter into power purchase agreements with an advanced nuclear reactor. It extends the maximum length of these agreements from 10 to 40 years. These changes in the law will help ensure innovative, new reactors are built.

Finally, the Committee understands many of these advanced reactor designs require high-assay, low-enriched uranium. In plain speech, the uranium of our current fleet is enriched to about 5 percent. Many advanced designs will need about 20 percent.

Our nation needs the capability to provide this fuel, and I appreciate the pragmatic approach that this bill takes to ensuring that the fuel will be made available when needed in the next few years.

Of course, being a world leader in the management of nuclear fuel is important at all points in the nuclear value chain, and our nation's used fuel policy is an area where we need U.S. leadership and resolution. I sincerely appreciate the Senate's efforts to resolve this critical issue, and I remain committed to working with you.

Nuclear, carbon-free power has always answered the call of this nation. It powers our homes, our businesses, our Navy. It enables deep space exploration. It solves medical challenges. It helps fund schools and essential services in local communities across our country. And as our focus on climate change becomes more intense, the nuclear industry provides a critical, carbon-free energy solution.

I look forward to working with you to ensure that this American technology continues to provide these essential benefits. The future we need cannot happen without nuclear. Your help, your active support is urgently needed.

Thank you and I look forward to your questions.

[The prepared statement of Ms. Korsnick follows:]

Testimony for the Record
Nuclear Energy Institute
Maria Korsnick, President and CEO

Committee on Energy and Natural Resources
United States Senate
April 30, 2019

I am Maria Korsnick, President and Chief Executive Officer of the Nuclear Energy Institute (NEI). I appreciate the opportunity to testify on the Nuclear Energy Leadership Act (NELA), S. 903.

NELA is a vital piece of legislation that will help enable the development, demonstration, and deployment of advanced nuclear power systems. It is imperative that the federal government and the private sector partner in achieving NELA's goals. The electricity sector in the United States has undergone significant transformation over the last decade and that transformation will continue. Ensuring that advanced reactors are available to the market by the early 2030s is essential to ensuring a secure and resilient electricity sector well into the future.

The United States is no longer the sole supplier of nuclear reactors; we are in a race against other countries to capture a growing international market share. NELA's implementation is critical to positioning the United States for the future both domestically and internationally and will help the United States regain its position as global leader in nuclear energy.

Nuclear power is vital to the electricity system

Currently, 98 commercial nuclear power plants provide nearly 20 percent of America's electricity and more than half of the emissions-free electricity.[1] Because electricity generation from nuclear energy does not release carbon dioxide and other harmful air pollutants, by maintaining a strong nuclear fleet, the United States will not have to choose between the health of its electric grid and the health of its citizens. Nuclear plants run 24 hours a day, 7 days a week producing power with unmatched reliability and have the added benefit of having all their fuel on site for 18-24 months. Nuclear plants are hardened facilities that are protected from physical and cyber threats, helping to ensure we have a resilient electricity system in the face of potential disruptions.

New advanced reactor designs must be commercially available by the early 2030s to meet domestic and global energy needs. This is a challenging task but one that is necessary if the U.S. is to maintain the reliable electricity service Americans now enjoy and meet its clean air commitments. The U.S. Energy Information Administration forecasts the retirement of 140 gigawatts of capacity by 2040 in the U.S.[2] In addition, the EIA estimates that demand for electricity in the U.S. will expand by almost 15 percent during that time. Advanced nuclear plants can be a part of the clean domestic electricity landscape.

[1] U.S. Energy Information Administration – Electric Power Monthly (February 2019).
[2] U.S. Energy Information Administration – 2019 Annual Energy Outlook: Table A8.

Focusing only on the need for additional electricity in the U.S. in the upcoming decades would mistakenly overlook the likelihood of and the need for a significant increase in electricity demand worldwide. There are still nearly 1 billion people in the world without access to electricity.[3] Providing them with a reliable source of electricity will significantly raise their standard of living. In addition, many countries are looking to a rapid expansion of nuclear generation to address their growing electricity needs. Therefore, it is imperative that new U.S. advanced reactors be available soon for both domestic and international deployment.

U.S. national security interests are at stake in the development of advanced nuclear technology

From the dawn of nuclear energy, a dominant position in civilian nuclear power enabled the United States to advance multiple national-security interests. Leadership in nuclear energy allowed the United States to promote the highest global standards for nuclear safety, security and nonproliferation; to protect our friends and allies against energy insecurity and adverse foreign influences; to maintain a healthy domestic supply chain for our nuclear Navy and major DOE programs; and to promote environmental goals through generation of the majority of our nation's carbon-free power, among other critical interests.

In recent decades, Russia and China – guided by strategic goals and backed by strong state support – have displaced the United States as the global leader in nuclear energy. Through its state-owned and state-supported company Rosatom, Russia has brought five reactors online in the past five years and today has six reactors under construction. There are 17 reactors of Russian design under construction worldwide, of which only 6 are being built in Russia. The other 11 reactors are being built in Bangladesh, Belarus, India, Slovakia, Turkey and Ukraine.[4] In just the past five years, China has brought 26 reactors online and today has 13 additional plants under construction. China is aggressively becoming a key supplier to the global market, including engagement in the United Kingdom.

The future of global nuclear leadership is at a crossroads. The lower cost, lower power, inherent safety and wider applications of advanced reactor designs make nuclear power a practical option for many more countries than use nuclear power today. The supplier will forge a special relationship with these counties over the century-long life of its nuclear program – from site characterization to regulatory development, training, engineering and construction, operations and maintenance, security services and finally decommissioning. More broadly, the dominant global supplier will exert considerable influence on nuclear policies and practices.

If the United States is to maintain its leadership in global nuclear safety, security and nonproliferation; if we are to continue helping our friends and allies against foreign leverage through energy supply; if we are to maintain the domestic supply chain that supplies not just our plants but also our nuclear Navy; and if we are to maintain our nation's majority of carbon-free power, then we must lead in the development and commercialization of the next generation of civil reactors.

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[3] International Energy Agency - 2018 World Energy Outlook: Electricity Access Database
[4] International Atomic Energy Agency – Power Reactors Information System (PRIS) Database

Nuclear energy is at a crossroads in the U.S.

NEI supports a nuclear future that includes the existing fleet with subsequent license renewals, additional large light water reactors (LWRs) and advanced reactors, including advanced water-cooled small modular reactors (SMRs) and non-light water reactors. Evolutionary LWR designs are already commercially available, with the two AP1000 units under construction at the Vogtle site in Georgia that are expected to come online in 2021 and 2022. Advanced water-cooled SMRs are expected to be available by the mid-2020s and larger advanced non-LWRs are expected to be available in the late 2020s or early 2030s while micro-reactor technology is expected to be commercially available in the mid-2020s.

The domestic nuclear fleet is a central part of our nation's critical infrastructure and should not be taken for granted. In the last six years, seven units that produced 5,300 megawatts of power have closed. Companies that own nuclear plants have announced the scheduled closure of an additional twelve units of 11,000 megawatts capacity. Over the course of a year that amounts to 90 million megawatt-hours of clean generation that will have been lost by the early closure of these units. That would be equivalent to taking offline the amount of electricity used to power 8.6 million American homes. That's more homes than in all of New York, or all of Florida – and a massive quantity of clean, carbon-free energy.

Although the U.S. led the world into the age of nuclear energy, we are losing ground to other countries with substantial, state-funded advanced reactor programs. The Russians are operating two commercial liquid-metal fast-reactors and the Chinese are bringing a commercial high-temperature gas pebble-bed reactor online . By the time the U.S. has an operational pebble-bed reactor, the Chinese will likely have 10 years of operational experience. This is not a comment about the U.S. developer, but rather a comment about the lack of our government's investment in new technologies. To avoid being left behind, we must focus on regulatory reform, R&D infrastructure, and development and deployment of new technologies. NELA is instrumental in this effort.

Planning for the future

The electric utility sector in the United States is rapidly evolving. I believe it is in the best interest of the U.S. that nuclear power remain a significant and growing supply of clean electricity as this evolution continues. Therefore, it is imperative that the commercial nuclear industry in the U.S. continue to rapidly innovate new products and designs so that these products are available when the market needs them. As the electric utility sector in the United States looks to the future, it is interesting to note some long-term plans from a few utilities.

Xcel Energy, on its website, says "We've cut our carbon emissions by 38%, but we're not stopping there. We're aiming to achieve 100% carbon-free electricity by 2050. To achieve this goal, your energy will be a diverse mix of wind, solar, and other carbon-free resources."[5]

[5] Xcel Energy: "Your Clean Energy Future" (https://www.xcelenergy.com/carbon_free_2050)

Southern Company has announced, "We are establishing an intermediate goal of a 50 percent reduction in carbon emissions from 2007 levels by 2030 and a long-term goal of low- to no-carbon operations by 2050."

Furthermore, "over the long term, meeting our goals will require energy policies that support low natural gas prices and the development and deployment of more low- to no-carbon emitting energy resources."[6] Connecting the AP1000s at Vogtle 3 and 4 to the grid in 2021 and 2022 will be essential in meeting these targets.

Utah Associated Municipal Power Systems (UAMPS) states that "the electrical utility industry is in the midst of transformation due to the proliferation of new technologies, changing lifestyles, and new regulations targeting fossil fuels. UAMPS' Carbon Free Power Project encompasses three interconnected parts designed to help members cope with these changes and ensure that UAMPS' future energy supply is safe, clean, secure, stable and adequate for an energy-hungry, growing population. The CFPP provides tools for Energy Efficiency, embraces Distributed Generation (like rooftop solar) with wise rate structures, and is investigating Small Modular Nuclear Reactor technology to provide future baseload supply."[7] UAMPS is considering using NuScale Power's reactor technology.

The Nuclear Energy Leadership Act is vital

The bipartisan Nuclear Energy Leadership Act (NELA) is a vital piece of legislation that will help enable the development, demonstration, and deployment of advanced nuclear power systems and position the U.S. industry for both domestic and international expansion. A robust and vibrant advanced nuclear power industry requires:

- Innovative ideas and technology through private sector development
- An efficient and effective regulatory structure for licensing advanced reactors
- Research and development infrastructure
- Access to fuel
- Market demand
- A committed and vibrant workforce

The U.S. leads the world, hands-down, in innovative and entrepreneurial companies. NEI's members include approximately 20 advanced reactor developers with one or more designs being developed. These companies are developing designs with coolants including water, liquid metal, high temperature gas, and molten salt. The designs range in size from a few megawatt electric (micro-reactors) to a few hundred megawatt electric (small modular reactor) to the large gigawatt class reactor. Advanced nuclear reactor designs have many potential technological advantages (e.g., passive cooling even in the absence of an external energy supply; some designs operate at or near atmospheric pressure, which reduces the likelihood of a rapid loss of coolant; and extended operations between refueling and the potential consumption of nuclear waste as fuel,

[6] Southern Company: "Planning for a Low-Carbon Future" (https://www.southerncompany.com/content/dam/southern-company/pdf/corpresponsibility/Planning-for-a-low-carbon-future.pdf)

[7] Utah Associated Municipal Power Systems (UAMPS) – Carbon Free Power Project

reducing disposal issues). The majority of these companies are privately funded and all have a strong commitment to the development of safe, secure, and economically viable reactors. Public-private partnerships, in different forms, have benefitted many of these companies, enabling them to leverage their own resources and thereby accelerate development of their technologies. NuScale submitted its design certification application in 2017 and NRC is performing the review on schedule. Kairos, Oklo, TerraPower, Terrestrial Energy, and X-energy are all at different levels of engagement with NRC. Continued partnerships with the federal government are essential to the rapid and successful development of these designs.

In order for the advanced reactor community to be successful, the NRC's regulatory structure for licensing advanced reactors must be efficient and effective and the companies must have access to the necessary research infrastructure. The Nuclear Energy Innovation Capabilities Act and the Nuclear Energy Innovation and Modernization Act, both of which have been signed into law, will help address these issues.

The Nuclear Energy Leadership Act is the key to addressing the workforce, access to fuel, and market demand issues as well as reinforcing the need for a robust R&D infrastructure. NELA's policies will address market demand by providing a pathway to demonstration for multiple designs and establishing policies that enable the long-term valuation of power from these reactors.

Nuclear Energy Leadership Act Provisions

The Nuclear Energy Leadership Act does an admirable job of addressing high-priority items such as power purchase agreements, R&D goals including demonstrations, strategic direction for DOE, a new fast-neutron user facility, fuel supply, and workforce development.

Power Purchase Agreements and Pilot Program

Commercial deployment of renewable energy technologies has benefitted from federal and state policies that have created robust renewable energy markets and have attracted considerable private sector investment to complement federal R&D investments. NELA takes an important step toward creating a similar market-inducing policy environment for advanced nuclear energy by authorizing 40-year Federal Power Purchase Agreement (PPA) authorities. These authorities would provide federal facilities the ability to enter into multi-decade PPAs with developers of advanced reactors, to better match the very long operational lifetimes of most nuclear power plant concepts. We heartily endorse this provision and the establishment of a pilot program for PPAs. Requiring the Secretary to enter into at least one PPA by Dec 31, 2023, will be particularly beneficial. Further allowing these PPAs to pay a higher-than-average market rate if the agreement fulfills reliability and resilience requirements will appropriately compensate SMR and other advanced nuclear plants for the full value of the electricity they supply. The reactors being developed today will offer capabilities such as black-start and islanding capabilities that will be valuable to maintaining a secure national infrastructure. The act should permit all PPAs to pay a higher average market rate.

Advanced Nuclear Reactor Research and Development Goals

We applaud NELA's focus on demonstrating advanced nuclear technologies. Historically, the federal government partnered with the nuclear industry to build the first commercial reactors in the United States. Doing so helped prove that the technology was viable and helped establish the market. Partnerships between the federal government and the private sector for advanced reactor demonstrations will also be valuable in establishing market pull for these new designs and will enable potential customers to see the reactors in operation. NELA defines a demonstration project as an advanced reactor operated as (1) generating electricity for an electric utility system or (2) in any other manner that demonstrates suitability for commercial application. This approach provides the developer with the flexibility to create a reactor demonstration that best suits its long-term commercialization objectives. We applaud the aggressive deadlines in NELA for demonstrating advanced reactors:

- To the maximum extent practicable complete not fewer than two advanced nuclear reactor demonstration projects by not later than December 31, 2025
- To the maximum extent practicable establish a program to demonstrate not fewer than two and not more than five additional operational advanced reactor designs by not later than December 31, 2035

It is appropriate that the demonstration program outlined in NELA include diversity in designs including size, coolants, fuel types and neutron spectra. A challenge in crafting a public-private partnership demonstration program is in trying to ensure that the designs being demonstrated will be of interest to potential customers. NELA attempts to address this issue by requiring that the Secretary of Energy ensure that each evaluation of candidate technologies for demonstration is completed through an external review by a panel that includes at least one representative of an electric utility and an entity that uses high-temperature process heat. Including an end-user perspective into the selection of demonstrations will be essential to ensuring that the products being developed are of interest to the market and will maximize the impact of the public-private partnerships.

Nuclear Energy Strategic Plan

NELA requires the Department of Energy's Office of Nuclear Energy (DOE NE) to develop a ten-year strategic plan and update it every two years at a minimum. The development of a strategic plan with appropriate input from stakeholders would guide the Department's actions and provide a clear indication to the developers, the investment community, and the potential end users as to how the DOE is going to support and partner with the industry while outlining its goals. NEI recommends that this strategic plan address all phases of the fuel cycle for advanced reactors and include a clear strategy for supporting the development of High Assay LEU fuel cycle capabilities and infrastructure.

NEI also recommends that within the strategic plan, DOE NE establish a Nuclear Energy Affordability Initiative to focus its R&D program to significantly increase emphasis on reducing the cost and schedule to construct new nuclear plants (particularly advanced reactors, including water-cooled SMRs), and to reduce the operation and maintenance costs for both existing and new nuclear plants. The Nuclear Affordability Initiative should not become a program, but rather a national initiative focused on driving deployment by setting aggressive affordability targets for nuclear plants and then focusing R&D dollars on areas of research that offer the most promise in meeting those targets. As such, the Initiative should not receive funding separate from other programs, but rather would focus the funding of relevant programs to partnerships with industry, laboratories, universities and others to achieve mutually-agreed goals. Setting aggressive affordability targets within the strategic plan would signal to the developers, the investment community and the end-users that the DOE believes that the cost of new nuclear can be significantly reduced and is committed to achieving this goal.

Versatile Test Reactor

The Versatile Test Reactor (VTR) was originally authorized in the Nuclear Energy Innovation Capabilities Act. The VTR will be a versatile fast-spectrum test reactor; a testing capability that the United States once possessed. Currently U.S. companies that need access to a fast neutron testing capability must utilize a Russian research reactor. However, U.S. researchers and developers encounter multiple barriers when seeking access to the Russian research reactor, including export control concerns, intellectual property rights, and international transportation issues.

Developers need a domestic fast neutron irradiation capability to support the continuous development of new materials and fuels for advanced reactors, particularly as a means to improve future fuel design iterations as has been done with LWR technology in recent decades (e.g., accident tolerant fuel development). In February 2017, the Department of Energy's Nuclear Energy Advisory Committee issued a report recommending "that DOE-NE proceed immediately with preconceptual design planning activities to support a new test reactor (including cost and schedule estimates)." When operational, the Versatile Test Reactor will support both advanced reactor development and the current fleet while also helping to revitalize the U.S. nuclear industry and reestablish U.S. leadership in nuclear.

Advanced Nuclear Fuel Security Program

The current fleet of reactors utilizes uranium enriched to approximately 5% uranium-235. Many but not all advanced reactors being designed and at least one advanced fuel for the existing fleet will need uranium enriched up to 20%. Uranium enriched to between 5% and 20% is referred to as high-assay low enriched uranium (HALEU). Low enriched uranium is defined as uranium with an enrichment of less than 20% uranium-235. Currently the only domestic enrichment facility in the U.S., the URENCO USA facility in New Mexico, supplies enriched uranium up to 5% uranium-235. The development, demonstration, and deployment of many advanced nuclear technologies is in jeopardy since it is unclear whether a HALEU fuel infrastructure will be in place when they are ready to enter the market. That certainly makes an investment into a HALEU fuel infrastructure highly unlikely. We appreciate that NELA recognizes that the federal government is in a key position to accelerate the development of this infrastructure and advanced reactors by providing an interim supply of HALEU fuel and supporting the development of transportation infrastructure. As advanced reactors are developed and deployed, the market demand for HALEU will increase and the commercial fuel supply infrastructure will be developed.

We appreciate the attention that Congress continues to pay to this issue and the support that has been provided through Congressional appropriations for the processing of spent high-enriched fuel to create HALEU. NELA is essential to ensuring that both advanced reactors and the associated fuel supply infrastructure are developed expeditiously. NELA appropriately instructs the Secretary of Energy to make available specific quantities of HALEU by December 31, 2022, and additional quantities by December 31, 2025. These quantities are generally consistent with the demand outlined in our July 2018 letter to Secretary Perry in which NEI outlined the industry's HALEU needs through 2030. As the domestic enrichment capability is expanded, the associated transportation infrastructure will have to be developed. Currently the transportation packages that are licensed for HALEU can only carry very small quantities of HALEU. NEI appreciates NELA's attention to this issue by requiring the Secretary to establish an RD&D program for the development of NRC-licensed HALEU transport packages. Without the legislative support provided by NELA for the development of a domestic fuel supply infrastructure, the development of advanced reactors in the U.S. will likely be delayed.

University Nuclear Leadership Program

Maintaining a pipeline of young professionals is key to the long-term success of the nuclear energy industry both for the operating fleet and the advanced reactor developers. We appreciate Congress' commitment to developing the workforce through its appropriations support of the Integrated University Program. Establishing the University Nuclear Leadership Program, through the joint efforts of the Secretary of Energy, the Administrator of the National Nuclear Security Administration, and the Chairman of Nuclear Regulatory Commission is another key step toward ensuring that U.S. universities maintain their world-renowned expertise and that a pipeline of young professionals is ready to support the entire range of disciplines in the United States nuclear power enterprise.

Conclusion

The industry is grateful for the bipartisan Congressional commitment to nuclear energy that resulted in the enactment of NEICA and NEIMA. We appreciate and applaud the continued bipartisan support that inspired NELA. With this continued support and the dedication of the industry, I am confident that the U.S. will regain its leadership role in nuclear technology and generation.

On behalf of NEI and its members, I thank the bill's sponsors for introducing this important legislation. Passage of the Nuclear Energy Leadership Act will benefit all Americans by helping to retain the energy diversity and clean air benefits nuclear plants provide. The legislation also will ensure that these economic engines continue to be the backbone of the nation's electric infrastructure. NELA will facilitate the development and deployment of innovative nuclear reactor technologies. We look forward to working with Congress to pass this bill.

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The CHAIRMAN. Thank you, Ms. Korsnick, we appreciate that.
Mr. McManus, welcome.

STATEMENT OF MARK MCMANUS, GENERAL PRESIDENT, UNITED ASSOCIATION OF JOURNEYMEN AND APPRENTICES OF THE PLUMBING AND PIPE FITTING INDUSTRY OF THE UNITED STATES AND CANADA, AFL-CIO

Mr. MCMANUS. Good morning, Chairman Murkowski, Ranking Member Manchin and members of the Committee. Thank you for the warm welcome.

My name is Mark McManus, and I'm the General President of the United Association, or the UA, which represents America's union plumbers, pipefitters, welders, sprinkler fitters and HVAC service technicians. On behalf of more than 350,000 men and women members of the UA, I want to thank you for the opportunity to testify about the future of the U.S. nuclear power and the Nuclear Energy Leadership Act.

Whether they're working on a job or volunteering in their communities, UA members, like most Americans, take a fact-based, commonsense approach to everyday problems. That is precisely the approach that this country needs when it comes to nuclear energy. Quite simply, any fact-based, commonsense approach to meeting our future energy needs while addressing climate change must include major investments in nuclear energy.

It is well past time that we turned the page on any lingering irrational fears of carbon-free energy source that already provides 20 percent of our electricity and hasn't injured or killed a single person in more than a half a century we've consumed it.

The truth is that nuclear energy is already safe, cost-effective, and reliable, and the development of advanced technologies made possible by NELA would make it even more so.

In my view, the success of NELA and the nuclear industry depends not only on well-trained nuclear engineers and scientists, a focus of NELA, but also well-trained building trades craftspeople to build and maintain the nuclear facilities themselves. In fact, one of the major reasons for the industry's excellent safety record is the top-notch training of the UA and other craftspeople that work on nuclear facilities.

We spare no expense when it comes to the skill developments. Through collectively bargained contributions to joint trust funds, the UA and our signatory employers invest over 220 million private, non-tax paying dollars each and every year in training. A sizable portion of this is devoted to the UA members working in the nuclear industry.

Since the mid-'80s, the UA and other building trades unions have worked closely with the nuclear utilities to ensure that our members are trained to specific needs of the industry. I discuss this partnership further in my written testimony. Overall, it's been a great success.

Project labor agreements, or PLAs, are another tool used by nuclear utilities to protect their investments and ensure safety and success on their projects. PLAs cover over 80 percent of the U.S. reactors currently in operation and, as explained in my written testimony, they meet a number of critical needs for the utilities. The

Federal Government would be well-served to protect its own investments by demanding PLAs on any projects made possible by NELA.

Although the energy and the environmental benefits of investing in nuclear are appropriately front and center, the tremendous economic benefits generated by these investments should not be overlooked.

For a real-time example of job-creating potential of nuclear power look no further than the ongoing work on two nuclear reactors at Plant Vogtle in Georgia. At this very moment there are 7,000 workers on the project, and when construction reaches its peak that number will rise to 9,000 workers. Senators, these are well-paying clean energy jobs Americans have been waiting for.

Let me close by offering one last recommendation to the Committee. Don't stop at NELA. Nuclear energy has the potential to substantially improve our energy security, dramatically reduce our carbon footprint and deliver enormous benefits to our country. However, to fully realize that potential I believe we need to take a hard look at every reasonable opportunity to expand nuclear power. This includes encouraging the development of new plants and units through commonsense reforms to permitting and readily available loan guarantees. And it also includes taking action to prevent unnecessary or premature closure of existing plants and units.

Thank you again for the invitation and the opportunity to testify.

[The prepared statement of Mr. McManus follows:]

Mark McManus, General President
United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States and Canada, AFL-CIO

Before the U.S. Senate Committee on Energy and Natural Resources
Hearing on U.S. Leadership in Nuclear Energy and to Receive Testimony on NELA

April 30, 2019

My name is Mark McManus and I am the General President of the United Association of Journeymen and Apprentices of the United States and Canada ("UA"), which represents America's union plumbers, pipefitters, welders, sprinkler fitters, and HVAC technicians. On behalf of the more than 350,000 members of the UA, I want to thank you, Chairwoman Murkowski, Ranking Member Manchin, and members of the Committee, for the opportunity to testify about the future of U.S. nuclear power and the Nuclear Energy Leadership Act ("NELA"). I was especially pleased to accept this invitation to testify because I believe that the kind of bipartisan leadership featured in today's hearing and in the development of NELA is what is necessary to address the energy and environmental challenges facing our country.

Whether they are working on a job or volunteering in their communities, UA members—like the vast majority of Americans—take a fact-based, common sense approach to everyday problems. That is precisely the approach that our country needs when it comes to nuclear energy. Quite simply, any fact-based, common sense approach to meeting our future energy needs while addressing climate change must include major investments in nuclear energy. It is well past time that we turned the page on any lingering irrational fears of this carbon-free energy source that already provides 20 percent of our country's electricity—50 percent of electricity in Illinois—and hasn't injured or killed a single person in the more than a half century we've consumed it. And, for all of the discussion about where to store nuclear waste, the fact of the matter is that the amount of waste we are talking about is minimal[1] and our country knows how to store it.

The truth is that nuclear energy is already safe, cost-effective and reliable, and the development of advanced nuclear technologies made possible by NELA would make it even more so. The UA believes that proactive federal leadership in this area is critical and that the public-private partnerships facilitated by NELA—and the demonstration projects arising from those partnerships—will help to achieve the goal of reestablishing U.S. preeminence in nuclear energy.

In my view, the success of NELA and the nuclear industry as a whole depends not only on well-trained nuclear engineers and scientists, a focus of NELA, but also well-trained building trades craftspeople to build and maintain the nuclear facilities themselves. Indeed, a major reason for the nuclear industry's excellent safety record is the top-notch training of the building trades craftspeople to whom these facilities are in large part entrusted. The UA is proud to represent many of the men and women who perform this work, and we spare no expense when it comes to their skills development. Through collectively bargained contributions to joint-trust funds, the UA and its signatory employers invest over 200 million private, non-taxpayer dollars each year in training—a sizable portion of which is devoted to UA members who work in the nuclear industry.

[1] U.S. Department of Energy Website, *3 Reasons Why Nuclear is Clean and Sustainable*, https://www.energy.gov/ne/articles/3-reasons-why-nuclear-clean-and-sustainable (last visited April 23, 2019).

In my experience, the U.S. nuclear utilities that employ members of the UA and other building trades unions share our passion for safety and training and have cultivated a culture of safety in the U.S. nuclear industry that is without equal anywhere in the world. Since the mid-1980s, we have worked closely with nuclear utilities to ensure that our members are trained to the specific needs of our nuclear plants. One of the ways in which we have accomplished this is through the Nuclear Mechanic Apprenticeship Process, or N-MAP, which was developed by a tripartite committee of international building trades unions, contractors and nuclear utilities.

There are three basic elements to N-MAP. First, the apprenticeship programs of the relevant crafts—*i.e.*, pipefitters, electricians, boilermakers, millwrights, ironworkers and sheet metal workers—are reviewed to ensure that individuals who complete our programs emerge with the fundamental knowledge and skills necessary to work in a nuclear facility. Second, the apprenticeship programs themselves perform annual self-assessments to identify and correct any deficiencies in the delivery of the requisite training. The nuclear utilities and contractors also have the chance at this stage to weigh in with any concerns arising from job site experiences. Third and finally, N-MAP includes an equivalency process to verify, through experience or examination, the knowledge and skills of craftspeople who did not complete a traditional apprenticeship. In these ways, N-MAP enables utilities to avoid unnecessary and costly investments in redundant training, and to plan maintenance and other work in their facilities with full knowledge of the capabilities that each building trades craftsperson brings to the table.

In addition to working with the UA and other building trades to ensure that our training is responsive to the needs of the nuclear industry, nuclear utilities use Project Labor Agreements, or PLAs, to protect their investments and secure reliable access to the best-trained skilled labor available. PLAs, which cover more than 80 percent of the 98 reactors currently in operation in the United States, leverage established referral systems administered by the building trades in the area to verify the qualifications of the men and women who are dispatched to nuclear facilities. In fact, PLAs can help to ensure local hire or that a project includes women, minorities or veterans. We're particularly proud of our UA Veterans in Piping (VIP) program, which trains active duty military personnel for a job in our industry, at no cost to the government, to ease the transition back into civilian life.

PLAs are also exceptionally valuable tools for planning and coordinating construction, modification and maintenance projects at nuclear plants. PLAs establish uniform terms and conditions for all of the trades and site contractors on the project. In other words, on a nuclear project involving several crafts and contractors, PLAs ensure that there are consistent rules and procedures concerning wages and benefits, work schedules, overtime, holidays, and other issues, thereby promoting stability and maximizing efficiency over the life of the project. Moreover, PLAs include no-strike clauses, uniform dispute resolution procedures and other provisions that are designed to ensure that projects are completed on-time and without any disruptions or delays. For these and other reasons, PLAs are a widely adopted best practice for nuclear construction, modification and maintenance projects, and the federal government would be well-served to protect its investments by demanding a PLA on any such project made possible by NELA.

Although the energy security and environmental benefits of investing in nuclear energy are appropriately front and center, the tremendous economic benefits generated by these investments are equally impressive. The construction of a new nuclear plant is a career-defining opportunity for the men and women in this country who make a living in the trades. Building a new nuclear plant requires a broad array of crafts, along with various other project professionals, such as engineers, project managers, supervisors and superintendents. At its peak, construction of a new nuclear plant tends to employ upwards of 3,500 workers,[2] virtually all of whom are paid family-supporting wages and benefits. For a real-time example of the job-creating potential of nuclear power, look no further than the ongoing work on the two new nuclear reactors at Plant Vogtle in Georgia. At this very moment, there are 7,000 workers on the project, and when construction reaches its peak, the number of workers will rise to approximately 9,000.[3] Senators, these are the kinds of well-paying clean energy jobs that Americans have been waiting for.

The spillover benefits on the surrounding communities are difficult to quantify but undeniably great. Any time several thousand workers descend on an area for a large-scale construction project, the people and businesses which call that area home are going to see an enormous economic impact. The visiting workers rent local rooms, patronize local restaurants, shop at local stores, fill up at local gas stations, purchase tickets to local movie theaters, and much more. These projects, of course, produce major benefits for the regional and national economy as well. Consider the fact, for example, that a single new nuclear plant requires hundreds of new plant components, along with 300 miles of electric wiring, 44 miles of piping, 400,000 cubic yards of concrete, 130,000 electric components and 66,000 tons of steel.[4] Needless to say, orders of this scale are going to put a great many manufacturers to work—all hopefully in the United States of America—while requiring many of them to expand their operations and hire additional people.

Once a nuclear plant is up and running, several hundred direct permanent employees are required to operate it, and, again, these are well-paying jobs.[5] The average 1,000-megawatt plant supports 504 direct local jobs, which compares favorably to other sources, such as coal—the second highest—which supports 187 direct local jobs on average, and wind—the lowest—which supports only four such jobs on average.[6] And, each year the plant continues in operation, the local, regional and national economy will continue to reap direct and secondary economic rewards.

Let me close by offering one last recommendation to the Committee: don't stop at NELA. Nuclear energy carries the potential to substantially improve our energy security, dramatically reduce our carbon footprint, and deliver tremendous benefits to our economy. To fully realize that potential, I believe that we need to take a hard look at every reasonable opportunity to expand nuclear power, including by encouraging the development of projects through common sense reforms to permitting and more readily available loan guarantees, and by exploring all possible avenues to prevent unnecessary or premature closures of existing nuclear plants and units.

Thank you, again, for the opportunity to testify.

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[2] Nuclear Energy Institute, *Nuclear Energy's Economic Benefits - Current and Future*, 4 (2014), *available at* http://workshop1.cases.som.yale.edu/sites/default/files/cases/the_future_of_nuclear_in_connecticut/NEI_Economic Benefits of Nuclear.pdf

[3] Celia Palermo, *Plant Vogtle Seeing New Jobs and Getting New Money*, WRDW-TV NEWS 12 (Mar. 22, 2019), https://www.wrdw.com/content/news/Plant-Vogtle-seeing-new-jobs-and-getting-new-money-507542151.html.

[4] Nuclear Energy Institute, note 2, at 4.

[5] *Id.*, at 2.

[6] *Id.*

The CHAIRMAN. Thank you, Mr. McManus.

Mr. Merrifield, welcome.

STATEMENT OF HON. JEFFREY S. MERRIFIELD, FORMER COMMISSIONER, U.S. NUCLEAR REGULATORY COMMISSION, AND PARTNER AND ENERGY SECTION LEADER, PILLSBURY WINTHROP SHAW PITTMAN LLP

Mr. MERRIFIELD. Chairman Murkowski, Ranking Member Manchin and members of the Committee, it is a pleasure to be here today.

My name is Jeff Merrifield, and I'm testifying as a partner in the nuclear energy practice of Pillsbury Law, the world's oldest and largest nuclear firm. Additionally, I am Chairman of the Advanced Reactor Task Force for the Nuclear Industry Council, a member of the Board of ClearPath, and I am Chairman of E4 Carolinas, a 150-member energy association in North and South Carolina. I also advise Mark Peters with the GAIN program. That said, the comments today are my own.

I'm pleased that the Committee supports the development of advanced nuclear reactors. My testimony will focus on S. 903, the Nuclear Energy Leadership Act, the state of the advanced nuclear industry and opportunities for U.S. nuclear exports.

First, my punchline. I believe S. 903 is an excellent piece of legislation that will incentivize the development and deployment of advanced nuclear reactors in the United States and create a vibrant export market. It will enhance the ability of the U.S. to regain its leadership role in international nuclear commerce and will create thousands of lifelong, well-paying careers for blue- and white-collar workers.

S. 903 will provide economical, safe, clean energy options and allow us to meet vitally important carbon reduction and energy security objectives.

As it relates to Section 7 of the bill, the development of advanced reactors brings with it many benefits but the fuels used to operate these reactors will be of a greater variety in their form and composition. Most of these designs will use high enrichments of uranium, typically between 8 and 19.75 percent, otherwise known as HALEU. In comparison, the current reactors use uranium enriched between four and five percent.

As domestic supplies of HALEU do not currently exist, appropriate sources of this material will need to be identified or created. This includes the means to enrich uranium as well as transport and manufacturing.

The FY'19 Energy and Water Appropriations legislation helpfully included $20 million to begin processing used Navy spent fuel into HALEU. While important, the process the DOE is developing in Idaho may result in HALEU that contains residual radionuclides that may not be fully acceptable for some designs.

Additionally, the Department of Energy intends to award a contract to Centrus Energy to construct a 16-centrifuge cascade by 2020 to produce a small amount of HALEU. In parallel, Urenco has indicated it's considering adding a HALEU cascade to its enrichment facility in New Mexico.

While these steps are positive, Section 7 of the bill would set specific targets for DOE to make HALEU available, two metric tons by 2022 and ten metric tons by 2025. This provision is vitally needed to ensure that our advanced nuclear innovators are not held back by the inability of the market to timely supply this material.

The power purchase agreement (PPA) language included in Sections 2 and 3 will serve as a catalyst for advanced reactors. These PPAs create a financeable funding stream to incentivize investors on both the debt and equity side. When combined with investment or production tax credits, these can be enormously helpful in spurring private capital investment.

I strongly endorse Section 4 which authorizes a series of DOE advanced reactor demonstration projects. Under these provisions not fewer than two advanced reactor designs would be funded and completed by the end of 2025 and at least two and potentially five additional designs would be funded and completed by 2035.

Section 4 would also allow the demonstration of non-traditional users of nuclear reactors, including petrochemical processing, water desalinization, industrial scale hydrogen as well as potential uses in mining and powering remote communities. All of these create significant opportunities for exports and job creation.

I support the language included in Section 8 regarding the University Nuclear Leadership program and the funding it will provide for our nation's nuclear engineering programs.

On a personal note, I'm very pleased today that you invited Mark McManus to testify. As you see, my oldest son, Graham Merrifield, is a member of the United Association and is a pipefitter apprentice in the Concord, North Carolina branch of Local 421 where he's aspiring to become a nuclear pipefitter and welder and hopes to build advanced reactors.

Like their white-collar colleagues, the pipefitters, welders, electricians, plumbers and others who build and maintain nuclear plants are also an aging workforce. As this legislation continues to move swiftly toward adoption, I would urge the Committee to consider measures to ensure the steady supply of qualified technicians and craftspeople for this industry.

In conclusion, the companies and people who are developing advanced nuclear reactors will enable the United States to regain a leading role in the international nuclear export market. S. 903 is an excellent step toward ensuring that the U.S. remains a leader in nuclear technologies, and I urge its prompt adoption by this Committee as well as the appropriations needed to make it a success.

Thank you for allowing me to testify.

[The prepared statement of Mr. Merrifield follows:]

U.S. Senate Committee on Energy and Natural Resources Hearing on U.S. Leadership in Nuclear Energy and S. 903, the Nuclear Energy Leadership Act

The Honorable Jeffrey S. Merrifield, Commissioner
U.S. Nuclear Regulatory Commission (1998-2007)
Partner and Energy Section Leader, Pillsbury Winthrop Shaw Pittman LLP

April 30, 2019

Chairman Murkowski, Ranking Member Manchin and members of the Committee, it is a pleasure to testify before you this morning. I am appearing here today in my role as a Partner and Section Leader in the nuclear energy practice group of Pillsbury Winthrop Shaw Pittman Law Firm, which is the world's oldest and largest nuclear focused practice. In that role, I represent a wide diversity of advanced reactor developers, utilities, nuclear suppliers and other stakeholders in the nuclear industry.

Additionally, I am the Chairman of the Advanced Reactor Task Force for the Nuclear Industry Council (NIC) which is the leading business consortium advocate for nuclear energy and American nuclear exports. I am also a Member of the Board of ClearPath a conservative clean energy foundation as well as the Chairman of E4 Carolinas which is a 150+ member "all-technologies" energy association for North and South Carolina. With those caveats, the comments I am making today are my own.

My testimony today will focus on S. 903, the Nuclear Energy Leadership Act, the state of the advanced reactor industry, the potential opportunities for growth and export of U.S. nuclear technologies, and areas where support from Congress and the Trump Administration would be helpful in spurring these positive developments.

Over the last several years, Congress has enacted a series of nuclear focused acts that have been very helpful to advanced nuclear reactor developers, and I commend this Committee and its counterparts in Congress for the bipartisan efforts that have been made in support of clean nuclear energy over the last several years. At a time when the spirit of bipartisanship has waned in other parts of this town, I commend the Chairman, the Ranking Member and other members of this Committee for continuing the long legacy of cooperation and engagement in addressing our nation's vital energy policy needs.

I am pleased that the Committee is moving to provide support for the development of advanced nuclear technologies. I personally believe that we must take prompt and significant action to address the impacts of global climate change and I am convinced that nuclear power plays a key role in that regard. Today, nuclear power provides almost 60% of the carbon free energy in the U.S. and 35% worldwide. If we are to make any appreciable reduction in global carbon emissions, nuclear must remain a vital and growing source of clean energy here and abroad. The efforts of this Committee are key in that regard.

The E4 Carolinas energy association, that I chair, has over 150 members who are users, developers and supporters of wind, solar, fossil and nuclear energy as well as smart grid and energy storage technologies. Our organization is dedicated to the notion that no single technology will be able to address our nation's energy and power needs and for this reason we are home to some of the nation's leading hubs for smart grid, energy storage, advanced construction and advanced reactor technologies. We recognize that while we have made tremendous strides in the deployment of renewable assets, principally wind and solar, in order for us to meet our future power and industrial needs in this country, nuclear energy must remain a vital component of our nation's energy mix.

My detailed comments today will not focus on the existing nuclear fleet as I will leave those matters to other panelists, but I will say that it is vital that we maintain our existing nuclear plants in the U.S. As Germany and several U.S. states have shown, the elimination of existing, safe nuclear plants in favor of a "renewables only" program has only resulted in increased carbon emissions. Our country needs to deploy more wind and solar assets, but in order to address climate change, we will need to maintain our current nuclear units, and in my view, double the amount of nuclear power that we have in this country over the next twenty years.

During the four years I have chaired the Nuclear Industry Council (NIC) Task Force on Advanced Reactors, I have had the opportunity to witness first-hand the growth of interest in advanced reactor technologies, not only here in the United States but around the world, specifically during trade missions the NIC has led to a number of countries that are considering deployment of U.S. nuclear technologies. As you may know, there are significant parallel efforts underway in Canada to deploy advanced reactors, and I am pleased that the Nuclear

Regulatory Commission (NRC), and its counterpart the Canadian Nuclear Safety Commission, are working to identify methods where they can collaborate on braking down barriers and simplifying the process to allow bilateral recognition of regulatory review methods and standards.

There are a variety of other countries around the world in Africa, Asia and South America which currently do not produce nuclear power, but who are looking at advanced nuclear energy technologies, that are smaller, easier to build and have enhanced safety features as a potential source of clean power and desalination. These are real export opportunities for our country. Furthermore, as North America has among the most advanced high temperature gas, molten salt and fast reactor technologies available, we must not lose this opportunity to effectively compete on the world stage.

Now I would like to turn to S. 903, the Nuclear Energy Leadership Act.

Let me get to my punchline first: I believe S. 903 is an excellent piece of legislation that will incentivize the development and deployment of advanced nuclear reactors in the United States. It will help enhance the ability for the U.S. to regain its leadership role in the international nuclear energy marketplace, and will assist in creation of many thousands of lifelong, well-paying and satisfying careers for blue and white collar workers alike. By spurring advanced nuclear deployment, S. 903 will provide flexible, economical, safe, clean energy options, and allow us to meet carbon reduction and environmental objectives that are critically important to the economic security of our country. For all of these reasons, I strongly encourage this committee to swiftly pass this legislation.

Now let me expand on some of the reasons for that statement.

Section 7 - Need for High Assay Low Enriched Uranium

The first area in which I would like to focus is Section 7 and the Advanced Nuclear Fuel Security Program.

While the pending development of advanced reactors brings with it the potential for improved economics, lowered operating costs, higher utilization factors, enhanced safety margins and greater modularity, the fuels used to operate these reactors will be of a much greater variety in their form and composition. Additionally, many, but not all of these advanced designs, will utilize higher enrichments (assays) of low enriched uranium (between 8% and 19.75%) a material that is referred to as HALEU. The enrichment of HALEU is higher than that utilized by current light water reactor ("LWR") fleet (typically 4%-5%) but is not so high as to constitute weapons grade material.

As I stated in a report I wrote on this subject back in February of 2018, "To fully document the potential for the advanced reactor designs, Third Way, which is a Washington, D.C.-based think tank, issued a report on May 18, 2017, that indicated that there are currently 56 advanced nuclear concepts in North America under development with large numbers also underway outside the U.S.[1] From information that the authors (Pillsbury) gathered, the vast majority of these reactor designs are planning to utilize higher enrichments of fuel, and some of these designs are proposed to come to the U.S. market in the mid to late 2020s. Further, a March 2017 survey of 18 leading U.S.-based advanced reactors developers found that 67% of the companies said that an 'assured supply of High Assay LEU' was either urgent or important."[2] As the development of a fuel supply and regulatory approval can take multiple years, work must begin immediately to ensure sufficient supply of HALEU.

The infrastructure for the production of civilian nuclear fuel, as well as the regulatory processes overseeing its production and use, has been based on the existing LWR market. Virtually every element of the nuclear fuel cycle[3] has been tailored precisely for these lightwater reactors. As development and future deployment of many of the current advanced reactor designs requires utilizing fuel with higher enrichments of uranium, appropriate sources of this material will need to be identified or created, as no commercial, domestic source currently exists. This includes the means to enrich uranium, transport it, manufacture fuel forms and store and dispose of spent fuel. For its part, the NRC will also need to tailor its regulatory framework to meet this need.

Since I wrote that report, there have been some developments in this area worth noting. First, the FY19 Energy and Water Appropriations Legislation (PL 115-244) that was passed last year, helpfully included $20 million to begin processing U.S. Navy spent fuel into HALEU fuel. While this was an important action, the proposed process that DOE is developing in Idaho may result in HALEU that contains residual radionuclide components that may not be acceptable for some

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[1] http://www.thirdway.org/infographic/the-global-race-for-advanced-nuclear
[2] Advanced Fuels – Looming Crisis in Fueling Advanced and Innovative Nuclear Reactor Technologies, ClearPath/Nuclear Infrastructure Council White Paper on High Assay Low Enriched Uranium, p.2.
[3] The nuclear fuel cycle includes all the steps needed to mine, process, enrich, manufacture, use, store and permanently dispose of radioactive materials, including U-235 based fuels that are used for civilian and naval power and propulsion purposes.

advanced reactor designs due to its neutronic characteristics.

Additionally, the Department of Energy (DOE) recently announced its intention to award a contract to Centrus Energy to utilize its American Centrifuge Technology for constructing a 16-centrifuge pilot cascade by 2020 to produce a small amount of HALEU for use in research and development. In parallel, Urenco has also indicated that it is considering adding a cascade to its enrichment facility in New Mexico that could also produce HALEU.

While all of these developments are positive, the language included in Section 7 would set out specific targets for the Secretary of Energy to make HALEU available for this developing market – 2 metric tons by the end of 2022 and 10 metric tons by the end of 2025. This is vitally needed to ensure that our nation's advanced nuclear innovators are not held back by the inability of the market to provide HALEU in a timely manner. Additionally, the provisions in the section that provide for DOE leadership in the development of HALEU transportation packages is needed as today we are relying on existing transportation packages that, while they are safe, are aging, are generally designed for a maximum of 5% enriched uranium, and are insufficient in quantity and volume to meet the future anticipated need for HALEU.

Finally, I would note that the existing fleet also stands to benefit from the provisions included in Section 7. Lightbridge Corporation, in collaboration with Framatome, is designing a metallic fuel, utilizing HALEU, for the deployment with the existing nuclear units, that has the the potential for enhanced safety improvements over current fuel, as well provide for the ability to increase the power output of existing nuclear reactors.

Sections 2 and 3 – Authorization of Long-Term Power Purchase Agreements

Over the years, our law firm has worked on behalf of our clients in deploying dozens and dozens of nuclear reactors around the world. One of the vital components, in both the domestic and international deployment of these reactors is the use of power purchase agreements to create a financeable funding stream that will incentivize investors on both the debt and equity side to finance these units. This capability, when combined with investment or production tax credits, both of which are admittedly outside of the jurisdiction of this Committee, can be enormously helpful in spurring the investment of private capital in energy innovation.

The language included in Section 2, which would modify the U.S. Code to allow 40-year power purchase agreements for public utilities, as well as the power purchase agreement (PPA) pilot in Section 3 of the bill, have the potential to serve as a vital "kick-start" for advanced reactor deployments here in the U.S. Armed with these commitments, advanced reactor developers will be able to more effectively engage with individuals and institutions that may be willing to invest in these innovative reactor technologies, but who need a bit of additional "assurance" that there is sufficient long-term demand to justify putting their capital at risk.

Section 4 – Advanced Nuclear Reactor Research and Development Goals

I would like to strongly endorse the provisions contained in Section 4 which call for a series of demonstration projects to be funded by the Department of Energy to spur the deployment of innovative advanced reactor designs. Under these provisions, not fewer than two advanced reactor designs would be funded by DOE and completed by the end of 2025. At least two, and potentially five additional designs, would be funded and completed by 2035.

As it has done since the establishment of its predecessor, the Atomic Energy Commission (AEC), the Department of Energy has historically played a vital role in supporting efforts of the private industry to develop and deploy innovative energy technologies. Our current fleet of nuclear reactors was a direct beneficiary of the supportive efforts of the AEC and DOE, as were the many thousands of wind turbines and tens of thousands of acres of solar cells that are dotted across our nation. It is perfectly appropriate that DOE should be assisting in the manner envisioned in the legislation, and I applaud the sponsors for their farsighted vision in including these provisions.

I would also note there is a subtle, but very important element to this section. The provisions in Section 4 do not simply refer to power generation facilities, but also for "other manners for the purpose of demonstrating the suitability for commercial application of the advanced nuclear reactor." This is noteworthy. Advanced nuclear reactors are not just about electricity production. The industrial grade heat that they can provide – ranging from 500 to 770+ Celsius – can be used to supplant natural gas for the processing of petrochemicals, the desalination of water, or can be used to create hydrogen on an industrial scale. No other source of power has the ability to conduct these activities with such heat density, and in a manner that has a minimal physical and carbon footprint. The future customers of these designs are not just large integrated utilities as has been the case in the past, but petrochemical producers, mining companies, remote communities, developing nations, and areas that have a desperate need for the abundant, clean, desalinated water that can be produced by these exciting technologies.

Section 8 – University Nuclear Leadership Program

Congress, and the members of this Committee, are to be commended for the time and effort that they have put into raising attention and supporting programs in science, technology, engineering and mathematics – known as STEM programs – to ensure that as a nation, we continue to produce the talented women and men who can enable the U.S. to remain a world leader in the development and deployment of cutting-edge technologies, including nuclear.

Dating to my days as a Commissioner of the NRC, I have supported efforts to maintain the vibrancy of our university-based nuclear engineering programs. However, in order to design and deploy advanced nuclear plants, the full range of engineers including mechanical, civil, electrical, chemical, computer, process and system engineers, among others, are needed to effectively design these nuclear plants. I am a Founding Board Member of the Energy Production Infrastructure Center (EPIC) at the University of North Carolina Charlotte and in 2008, with several others, helped obtain $75 million in funding to create a national center dedicated to training the next generation of energy-engineering professionals. This center was funded with tens of millions in industry support and embraces applied energy training, closely partnered with the energy industry, to produce its future graduates.

In building a nuclear power plant, or virtually any power plant, at least half of the total cost is typically associated with engineering and construction. Toward that end, EPIC is creating a National Center for Advanced Construction. This center will be dedicated to learning lessons from recent nuclear construction efforts and applying advanced methods and techniques in collaboration with a wide variety of engineering and design companies to reduce the cost and time needed to deploy nuclear reactors. You will be hearing more about this program in the months to come, but I would hope that the provisions in Section 8 would apply beyond those institutions that produce nuclear physicists, but also those colleges and universities producing engineers and analysts who are vital contributors to the deployment of advanced nuclear technologies.

Finally, the ability to deploy these tremendous advanced reactor designs is highly dependent on having the skilled women and men who can build them. In the time I have spent touring our nation's nuclear plants, it is quite clear that like their white collar colleagues, including the pipefitters, welders, electricians, plumbers and other tradespeople that build and maintain nuclear plants, also are an aging workforce. As this legislation continues to move swiftly toward adoption, I would urge the Committee to consider measures to ensure the steady supply of technicians and tradespeople for this industry as well.

Ensuring the Vitality of our Current Fleet and American Leadership in Nuclear Power

The companies and people who operate our nation's 98 nuclear power plants have done a tremendous service in providing clean, safe, reliable and resilient power. As a country, not only should we continue to support this key element of our carbon free generation, but we also need to adopt effective policy measures to support the private sector as it leads with the development a new generation of advanced nuclear reactors. It is these companies that will allow the U.S. nuclear industry to regain a leading role in the international nuclear export market. S. 903 is an excellent step towards ensuring that the U.S. remains a leader in nuclear technology, and I urge its prompt adoption by this Committee. I also strongly urge this Committee to work with your counterparts in the Appropriations Committee to ensure that these and other important efforts needed to accelerate advanced reactor innovation are fully funded in 2020 and beyond.

Thank you for allowing me to testify on this important subject.

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Advanced Fuels – Looming Crisis in Fueling Advanced and Innovative Nuclear Reactor Technologies

CLEARPATH

United States
NIC
Nuclear Infrastructure Council

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White Paper on High Assay Low Enriched Uranium

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I. Introduction

Over the last five years, the United States ("U.S.") has seen the development of a series of advanced non-light water nuclear reactors ("advanced reactors") which are intended to utilize various forms of coolants and moderators that are different than the light-water cooled/moderated nuclear reactors ("LWR") that are currently deployed in the U.S. Advanced reactors utilize molten salt, high temperature gas (such as helium), lead bismuth or other materials to provide a source of cooling, moderation and heat transport. Many of these advanced reactor designs have their origin in national laboratories and most of them were first conceptualized and tested beginning in the 1950s and 1960s.

As a result of U.S. decision to deploy light-water reactors for the U.S. Navy, and subsequently for the U.S. civilian fleet, with few exceptions, virtually all of the nuclear reactors developed and built in the U.S. have been pressurized water ("PWR") or boiling water reactors ("BWR").[1] One of the advantages of this is that there is a relatively uniform, common framework for supplying materials for these reactors, including the nuclear fuel for their operation.

While the pending development of advanced reactors brings with it the potential for improved economics, lowered operating costs, higher utilization factors, enhanced safety margins and greater modularity, the fuels used to operate these reactors will be of a much greater variety in their form and composition. Additionally, many, but not all of these advanced designs, will utilize a higher enrichment of fuel than the current light water reactor ("LWR") fleet.

To fully document the potential for the advanced reactor designs, Third Way, which is a Washington, D.C. based think tank, issued a report on May 18, 2017, that indicated that there are currently 56 advanced nuclear concepts in North America under development with large numbers also underway outside the U.S.[2] From information gathered by the authors, the vast majority of these reactor designs are planning to utilize higher enrichments of fuel, and some of these designs are proposed to come to the U.S. market in the mid to late 2020s. Similarly, a March 2017 survey of 18 leading U.S.-based advanced reactors developers found that 67% of the companies said that an "assured supply of High Assay LEU" was either urgent or important, with squarely 50% of the overall respondents saying it was "urgent."

As the infrastructure for the production of civilian nuclear fuel, as well as the regulatory processes overseeing its production and use, have all been based on the existing LWR market,

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[1] The exceptions include Ft. St. Vrain and Peach Bottom 1 which were high temperature gas reactors, and Fermi 1 which was a commercial fast reactor.

[2] http://www.thirdway.org/infographic/the-global-race-for-advanced-nuclear

virtually every element of the nuclear fuel cycle[3] has been tailored precisely for this market. As development and future deployment of many of the current advanced reactor designs requires utilizing fuel with higher enrichments of uranium, appropriate sources of this material will need to be identified or created, as no commercial source currently exists. This includes the means to enrich, transport, manufacture, store and dispose of this fuel.[4] The U.S. Nuclear Regulatory Commission ("NRC"), which is responsible for the regulation of all civilian uses of radioactive and nuclear material, will also need to tailor its regulatory framework to meet this need. This paper is intended to explain the current process for producing low-enriched fuel in the United States, the potential market for higher-enriched fuel that will be required by many of the advanced reactors under development, potential challenges that will be faced in supplying this higher-enriched fuel, and the regulatory changes that will be anticipated in the development of this material. The paper will also propose policy recommendations needed to accommodate the development, licensing and deployment of these reactors.

II. Background on U.S. Enrichment Capabilities

Uranium in nature consists of approximately 99.27% uranium 238 ("U-238") and 0.72% uranium 235 ("U-235"). In order to make it useful for power production purposes, natural uranium must be "enriched" so that the content of U-235 is increased, allowing the desired fission reaction to take place. In the U.S., LWRs utilize fuel that typically has been enriched to approximately 4.5 percent U-235 which is considered a "low-enriched fuel" ("LEU").[5]

Highly-enriched uranium ("HEU") is material that has been enriched to a level containing U-235 in a concentration of 20% or greater. HEU is a material of great concern from a security and non-proliferation standpoint because terrorists could use uranium of this enrichment to fashion a nuclear weapon. In addition to its potential use for weapons purposes, HEU is also utilized for the nuclear fleet operated by the United States Navy and for some research reactors. While the precise enrichment of naval reactor fuel is a military secret, many observers believe it ranges somewhere between 70% and 90%. Weapons grade uranium is considered material that has been enriched to a level containing U-235 in a concentration of 90% or greater.

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[3] The nuclear fuel cycle includes all the steps needed to mine, process, enrich, manufacture, use, store and permanently dispose of radioactive materials, including U-235 based fuels that are used for civilian and naval power and propulsion purposes.

[4] In parallel with the development of advanced reactor technologies, Lightbridge Corporation is developing an advanced metallic fuel design for light water reactors that has characteristics that could avoid fuel damage yet allow for increased power uprates from existing units. This fuel is designed to utilize higher enriched fuels (15-20%) and if Lightbridge is successful in getting utilities to adopt its fuel design, this could substantially increase the need for higher enrichments of uranium.

[5] There are some notable cases of plants using higher-enriched fuel. For example, Ft. St. Vrain used highly-enriched uranium (originally enriched up to 93.5%) within thorium-uranium carbide particles. *See* U.S. Nuclear Waste Technical Review Board, *Department of Energy-Managed Spent Nuclear Fuel at Fort St. Vrain* at 2 (2017). *See* K.I. Kingrey, *Fuel Summary for Peach Bottom Unit 1 High-Temperature Gas-Cooled Reactor Cores 1 and 2*, INEEL at 15-35 (2003). Fermi Unit 1 was enriched to approximately 25% U-235. *See* Oak Ridge National Lab, *Integrated Data Base Report-1993: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE at Table A.3 (1994).

As currently conceptualized, many of the current advanced reactors under development intend to utilize high-assay low-enriched uranium ("HA-LEU") as fuel to provide greater efficiency levels than what can be achieved using the enrichment levels found in the current PWR fleet.[6] As will be described in below, this material is not commercially produced in the United States.

A. Atomic Energy Commission/DOE/ U.S. Enrichment Corporation

Beginning with the Manhattan Project during the Second World War ("WWII"), the United States utilized a process known as gaseous diffusion to enrich uranium for military and civilian purposes. The first large gaseous diffusion facility was constructed in Oak Ridge, Tennessee during WWII. Known as the "K-25 plant," this facility provided weapons grade and non-weapons grade enriched uranium to the U.S. military until it ceased operations in 1987.[7]

In 1952, the Paducah Gaseous Diffusion Plant ("Paducah") was put into operation to provide additional enrichment capabilities for the U.S. nuclear weapons program and the U.S. Navy nuclear propulsion program. Paducah was later used to supply fuel for the U.S. civilian nuclear fleet as well as for similar reactors outside of the United States, until it ceased enrichment operations in 2013. A third gaseous diffusion facility, a sister facility to Paducah, was built and operated by Atomic Energy Commission in Portsmouth, Ohio from 1954-2001 and also produced both military and civilian-use enriched materials. Under the Energy Policy Act of 1992, the U.S. Enrichment Corporation ("USEC"), a quasi-private corporation, began to operate the Portsmouth and Paducah sites in 1993.[8] At that time, USEC was the one of the largest producers of enriched uranium in the world, and was the sole U.S.-owned producer of enrichment services. After each site ceased operation—in 2013 for the Paducah site and in 2011 for the Portsmouth site—the sites was turned back to the Department of Energy for decontamination and decommissioning.

In 2014, USEC emerged from a Chapter 11 Bankruptcy Proceeding as the Centrus Energy Corporation.[9] While Centrus continues to provide enriched-uranium supply services to the civilian nuclear market, it is no longer actively enriching uranium. Rather, Centrus is now down-blending uranium obtained from the Russian nuclear weapons programs or from other non-U.S. sources. Today, there is no U.S.-owned provider of uranium enrichment services.

B. Louisiana Enrichment Services – URENCO USA

In June of 2006, URENCO USA, which is a subsidiary of URENCO,[10] received a license to construct and operate a centrifuge enrichment facility called the National Enrichment Facility ("NEF"), owned by Louisiana Enrichment Services ("LES") in Eunice, New Mexico. This facility is currently licensed to produce 5.7 million separative work units ("SWU") of uranium

[6] HA-LEU is considered that material that has typically been enriched to between 5% and 20%.

[7] DOE, *K-25 Gaseous Diffusion Process Building*.

[8] Energy Policy Act of 1992, Pub. L. No. 102-486, 106 Stat. 2776.

[9] Centrus, *Centrus Energy Corp. Emerges from Chapter 11 Restructuring* (Sept. 9, 2014).

[10] URENCO is a European based provider of centrifuge enrichment services that is jointly owned by the governments of the United Kingdom, the Netherlands, and Germany.

per year.[11] According to URENCO USA, the NEF produced 4.7 million SWU in 2016.[12] The NEF utilizes centrifuges that were developed and manufactured in Europe by Enrichment Technology Company, Ltd., which is 50% owned by URENCO and 50% owned by Orano.[13] One of the advantages of SWU produced by centrifuge enrichment, rather than by diffusion, is that it only requires 1/10th the amount of power needed in diffusion to produce an individual SWU, which significantly reduces the cost of production.

Currently, NEF only produces LEU at levels of approximately 4.5%, but it is capable of modifying this facility to increase this level up to 19.75%.

While the plant is technically capable of undertaking this change, producing higher assay LEU at this facility would also require licensing changes. The NEF is licensed by the NRC to produce enriched uranium up to a maximum enrichment of 5%.[14] Producing uranium with a higher enrichment would require a license amendment from the NRC. LES would also need to enhance the security requirements at the site. Currently, NEF is a Category 3 facility under the NRC security definitions regarding the amount and enrichment of material that is undertaken at the site.[15] Category 3 is the lowest level of security (albeit highly robust and costly) required by the NRC in a system ranging from 1-3. Were NEF to begin enriching higher assay LEU (above 10% U-235), it would need to become a Category 2 facility, necessitating a higher level of security and a license amendment from the NRC.[16] License amendments can take several years to work their way through the NRC process.

C. Global Laser Enrichment/Silex

Beginning in the 1990s, Silex Systems Limited, based in Sydney, Australia, began to develop the Separation of Isotopes by Laser EXcitation ("SILEX") process. This process utilizes lasers to enrich uranium. In order to facilitate the potential commercial deployment of this technology in the United States, an Agreement for Cooperation between the governments of the United States and Australia was signed in May 2000.[17] In 2006, Silex signed a Technology Commercialization and License agreement with General Electric Company ("GE") to develop and commercialize the technology to enrich uranium for use in nuclear power reactors around the world. Since 2008, the project has been managed by the Global Laser Enrichment LLC ("GLE") subsidiary of GE that is owned by GE (51%), Hitachi (25%) and Cameco (24%).[18] In 2013, GLE completed

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[11] A separative work unit ("SWU"), is a standard measurement of the amount of work used to separate U-238 and U-235 in a uranium enrichment process.

[12] URENCO, *URENCO USA*.

[13] URENCO, *Enrichment Technology Company Limited*.

[14] *See* NRC, *Safety Evaluation Report for the National Enrichment Facility in Lea County, New Mexico, Louisiana Energy Services (NUREG-1827)*.

[15] Category 3 special nuclear material is enriched above natural uranium but to less than 10% U-235. *See* NRC, *Category 3 – Special Nuclear Material of Low Strategic Significance*.

[16] Category 2 special nuclear material is enriched above 10% or more U-235 but to less than 20% U-235. *See* NRC, *Category 2 – Special Nuclear Material of Moderate Strategic Significance*.

[17] SILEX, *SILEX Technology*.

[18] *Id.*

its Test Loop technology demonstration at GE's operations in Wilmington, North Carolina and received NRC commercial license approval for the technology.

On November 10, 2016, the Department of Energy announced that it had entered into contract negotiations to sell depleted uranium to GLE in order to re-enrich the material at what would be the world's first commercial laser enrichment facility. Proposed to be located in Paducah, KY, this facility would be used to re-enrich approximately 300,000 MTU of DOE tails inventories for further enrichment and use in nuclear fuel. This effort would result in approximately 100,000 MTU of natural grade uranium that would be made available for sale to the nuclear power industry over the next 40 years.[19] If built, the Silex facility would be capable of enriching uranium up to 19.75 percent.

III. The International Supply of Enrichment Services

According to the U.S. Energy Information Agency, 14 million SWU were purchased in the United States under enrichment services contracts from 12 sellers in 2016.[20] Of that 14 million SWU, the U.S.-origin share was 33% (principally from LES), and the foreign-origin SWU share was 67%. The primary foreign producers of SWU included: Russia with 22% of the total, Netherlands with 18%, Germany with 11%, and the United Kingdom with 7%.[21]

As can be seen from the table below, there are a variety of countries that currently produce uranium enrichment services. Some of these, including the U.K., France, Russia, and China are nuclear weapons states that market uranium enrichment services for export, and hence are technically capable of producing uranium in excess of the 5% level currently used in the civilian nuclear fleet. For this reason, these four countries would be considered the most likely sources of non-U.S. HA-LEU.[22] The authors have not undertaken individual contacts of all of these countries, but informally have received confirmation from sources that it is likely that each could provide such services if there were a commercial need to do so.

Table 1. International Supply of Enrichment Services

Country	***Company* and plant**	**2013**	**2015**	**2020**
France	*Areva*, Georges Besse I & II	5500	7000	7500
Germany-Netherlands-UK	*Urenco*: Gronau, Germany; Almelo, Netherlands; Capenhurst, UK.	14,200	14,400	14,900
Japan	*JNFL*, Rokkasho	75	75	75
USA	*Urenco*, New Mexico	3500	4700	4700

[19] *US DOE Sells Depleted Uranium for Laser Enrichment*, World Nuclear News (Nov. 11, 2016).

[20] EIA, *Uranium Marketing Annual Report* (Jun. 19, 2017).

[21] *Id.*

[22] While India and Pakistan are also weapons states that could, in theory, provide enrichment services in excess of 5%, we have identified no data or information indicating that either country has exported enriched uranium.

Country	*Company* and plant	2013	2015	2020
Russia	*Tenex*: Angarsk, Novouralsk, Zelenogorsk, Seversk	26,000	26,578	28,663
China	*CNNC*, Hanzhun & Lanzhou	2200	5760	10,700+
Other	*Various*: Argentina, Brazil, India, Pakistan, Iran	75	100	170
	Total SWU/yr approx	**51,550**	**58,600**	**66,700**

Source: World Nuclear Association *Nuclear Fuel Report* 2013 & 2015

Due to a number of policy choices and market failures, the U.S. currently has no domestically owned company that is capable of enriching uranium – at any level. While there is an overcapacity of enrichment services at the international level, not having sufficient enrichment capacity in the United States to meet domestic demand puts 20% of the U.S. power supply at risk if one or more of the sovereign-owned suppliers were to make the admittedly unlikely decision not to supply this material. Given the sensitive relations that the United States currently has with Russia and China, two large producers of enrichment, this scenario cannot be easily dismissed.

Further, the U.S. has no current domestic source of enrichment for HA-LEU, and if a U.S. company were to desire to procure materials at this level, it would currently be forced to seek such materials outside of the U.S. And, again, this sensitive procurement would need to occur with two of the four potential sources being countries with which the United States has a sensitive relationship. Additionally, as Russia and China are also trying to enter the market for advanced reactors, there is some risk that these countries might not be entirely cooperative with U.S. companies seeking HA-LEU materials.

IV. U.S. HEU/Down-blending/the Availability of HA-LEU

Beginning in 1996, as part of the "Megatons to Megawatts" program created to reduce the stockpile of U.S. and Russian nuclear weapons, DOE began a program to down-blend or convert its stockpile of HEU from former nuclear weapons into LEU for civilian nuclear fuel, making it unusable for nuclear weapons. HEU that is considered surplus is principally stored at the Y-12 Complex of the National Nuclear Security Administration ("NNSA") at a highly secure facility located at the Oak Ridge National Laboratory Site in Oak Ridge, Tennessee.[23] When ready for down-blending, these materials are shipped to a private sector facility owned by BWXT in Erwin, Tenn., or down-blended at DOE/NNSA facilities located at the Savannah River Site in Aiken, South Carolina, or at the Y-12 site.[24]

According to NNSA, approximately 186 metric tons (MT) of HEU has been slated for down blending. Of this amount, more than 143 MT have already down-blended which is equivalent to more than 5,500 nuclear weapons.[25] The remaining balance of HEU will be down-blended as

[23] NNSA, *U.S. HEU Disposition Program*.

[24] *Id.*

[25] *Id.*

additional nuclear warheads are dismantled. This material has generally been utilized for the commercial reactor fuel market or for the production of research reactor fuel.

Currently, the NNSA possesses a classified amount of HEU located at the Y-12 site for a variety of national security purposes. Of this amount, the largest share is reserved for use by the U.S. Navy Reactor Program to provide fuel for the approximately 100 nuclear reactors that propel American nuclear submarines and aircraft carriers. Using current force projections, the stockpile of HEU dedicated to this purpose, 160 metric tons of uranium, is expected to be sufficient to meet the Navy's fuel needs through 2050.[26]

Additionally, the NNSA has multi-ton stockpiles of HEU that have been reserved to meet international commitments for radioisotope production, including both targets and fuel, as well as additional fuel requirements for research reactors. Some of this material will be provided to these users at HEU levels in excess of 20% and some will be reserved to be down-blended at a level of 19.75% or less. Further, there is also a multi-ton volume of HEU that has been set aside for the space propulsion program.

Based on the most recent 2015 Secretarial Determination, there is very little HEU that is currently available to the developers of advanced reactors. There may be some very small volumes of "off-spec" or scrap HEU that could become available for modest research purposes, the volume and quality of this material is uncertain at best. As a result of meetings that the authors have had with key DOE and NNSA managers and staff, we believe that it is highly uncertain that (absent an updated Secretarial Determination freeing up additional HEU from one of the sources described above) the U.S. Government can serve as a significant or reliable source of HEU for down-blending HA-LEU. That said, there is an ongoing nuclear energy review within the Trump Administration that could address, among other things, a source of HA-LEU for the advanced reactor community.

V. <u>Transportation Challenges</u>

Since the development of the civilian nuclear reactor fleet in the early 1960s, with its principal focus on LEU, the production, transportation, and manufacture of higher assays of uranium, either HA-LEU or HEU, have been conducted almost entirely by or on behalf of the DOE or its predecessor the Atomic Energy Commission. With the development of advanced reactors and fuel technologies in the civilian market, there will be a variety of areas associated with the supply of this fuel that will require the time and attention of technology developers, DOE, and the NRC. One of the greatest concerns is the development and supply of sufficient fuel transport containers that can address the expected demand for these materials.

Even if Congress and the Trump Administration were able to identify appropriate domestic source(s) of HA-LEU, there remains significant challenges to transport this material in any volume due to the lack to appropriate and sufficient transport canisters. Higher assay uranium is more difficult to handle and transport due to the more complex geometric requirements needed to

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[26] <u>DOE, *Naval Reactors*</u>.

ensure the avoidance of accidents. As a general matter, the higher the enrichment, the smaller the volume of material that can be carried in an individual canister while avoiding criticality.

The possibility of a significant increase in the need for these canisters to transport higher volumes of materials enriched above 5% U-235 – based on market demands – combined with a limited number of approved canisters could create a potentially critical gap in the ability to transport sufficient quantities of these materials. New containers may need to be designed to improve shipping ability, which may also require the development of new design methods and codes. The industry may also need to develop alternative methods of transportation such as converting the uranium hexafluoride ("UF6") to an oxide or metal. In addition to the lack of sufficient transport containers for these materials, many of the potential containers may need recertification by regulatory authorities, including the U.S. Department of Transportation and the Nuclear Regulatory Commission. Licensing of these canisters can take 2 years, after the design and development work is complete. In summary, the time to take action to address this issue is short.

Outlined below are examples of some of the current container technologies.

Table 2. Sample Sizes of Cylinders for UF6 Transport[27]

Cylinder Model	Maximum Enrichment	Nominal Diameter (Inches)	Maximum Shipping Limit (Pounds)
Model 48Y	4.5%	48	27,560
Model 30B	5.0%	30	5,020
Model 8A	12.5%	8	255
Model 5B	100%	5	55
Model 1S	100%	1.5	1.0

While there is an insufficient amount of transport containers options for UF6, there will also need to be canisters that can transport larger volumes of uranium oxide powder and metal that is enriched beyond 4.5%. Although this paper has focused more attention to the supply of HA-LEU, we believe that the issue of transportation is potentially an equally significant issue that Congress and the Trump Administration should address in their review of matters associated with the deployment of advanced reactors.

[27] *The UF6 Manual – Good Handling Practices for Uranium Hexafluoride*, U.S. Enrichment Corporation, USEC – 651, Revision 8, January 1999, page 6.

VI. Conclusion

The development of advanced reactor technologies and advanced reactor fuels brings with it the potential for new and exciting opportunities for the U.S. nuclear industry and an opportunity to retain the historic American lead in the deployment of nuclear technologies worldwide and revitalize its nuclear fuel cycle supply chain. In the case of advanced reactors, their size, proliferation resistance, modular deployment and more cost effective designs could provide "game changing" opportunities for both domestic and international export of these technologies. However, these opportunities could be slowed or stopped because most of the advanced reactor developers in the U.S. are planning to rely on high assay low enriched uranium that is currently unavailable in the United States due an inability of the U.S. government or private industry to provide sufficient enrichment capabilities. Congress and the Trump Administration should undertake prompt action to address the lack of an adequate HA-LEU supply that could hinder the continued progress of advanced nuclear power plant deployment.

Policy Recommendations

1. Congress should direct the Secretary of Energy to establish, within five years, an adequate "strategic reserve" of higher assay LEU at an enrichment of 19.75% of 25 metric tons or more in order to serve the needs of the advanced reactor community in the near term.

2. Congress should direct the Secretary of Energy to develop a fast neutron test facility with a design requirement that it utilize higher assay LEU to serve as a catalyst for the early production of this material.

3. Congress should direct the Secretary of Energy to immediately declare a modest amount of its current inventory of highly enriched material, currently assigned to space or Navy propulsion needs, to be surplus in order to serve as the basis for establishing the strategic reserve outlined above.

4. Congress should direct the Secretary of Energy to conduct a study of various alternatives for minimizing the amount of HEU declared surplus under recommendation 3, including the potential to procure domestic uranium, enriched at 5% or higher to use as the feedstock for the down blending of HEU to 19.75%.

5. Congress should direct the Secretary of Energy to re-establish, within 10 years, the capability to ensure domestically enriched uranium at the level necessary to replenish the HEU materials that were declared excess in recommendation 3.

6. As an alternative to the down-blending strategy included in recommendation 3, Congress could direct the Secretary of Energy to facilitate procurement of HA-LEU in the domestic or international market.

7. Congress should direct the Secretary of Energy to determine if the current capabilities to transport HA-LEU, either in the form of UF6, metal, oxide, or in the form of fuel for advanced reactors is sufficient to meet the expected need, and if not, shall engage in a

program with maximum reliance on the private-sector to design and seek licensing of sufficient transport containers within 5 years.

8. Congress should direct the NRC and Department of Transportation to expedite the licensing of containers for UF6, metal, oxide or other forms of advanced reactor fuels.

9. Congress should direct the NRC to expedite the process for conducting the review and approval of Category 2 security facilities.

10. Congress should direct the NRC to expedite the process for conducting the review and approval of increased enrichments of uranium.

The CHAIRMAN. Thank you, all, we appreciate that. I really appreciate the positive encouragement that you have given for NELA.

I am going to ask a question, and this goes out to the whole panel here. You have all said, again, good, strong things about it. When you think about what we have done from a legislative perspective with the passage of NEICA and then the Nuclear Energy Innovation and Modernization Act, now we have NELA before us. What more needs to be done to really realize this nuclear renaissance that we talk about in, and again, these almost aspirational types of a reference?

Contained within NELA we have some pretty ambitious goals with the direction to DOE to get the demonstration of two reactors by 2025 and the demonstration of at least two additional ones by 2035. The question to you all is, is what we are doing within this legislation sufficient to demonstrate the representative technologies, the breadth of the innovative advanced reactor concepts? What more do we need to be doing in order to get where, I believe, all of us are hopeful? I throw that out to any one of you.

Mr. Merrifield? Go ahead and push your button.

Mr. MERRIFIELD. Senator, thank you very much.

The CHAIRMAN. Yes.

Mr. MERRIFIELD. I'll take the first crack at that.

As I said before, I strongly endorse this bill and I think this Committee, in this legislation, is doing a significant amount to really move the ball forward.

That said, you asked what else could be done? A lot of it results in activities outside of the scope of this Committee's jurisdiction—appropriations. You know, the framework that you put into this bill is vitally important. We need to pass it but we need to provide the funding to allow those demonstration reactors to be built.

The CHAIRMAN. So it is very important that Senator Alexander is here today.

Mr. MERRIFIELD. Very important that Senator Alexander is here.

The other thing, I think, which is important are export tools, making sure that the EXIM Bank is fully brought up to speed and can use its resources to help in the export of these technologies is vital. The overseas OPEC that has now been reauthorized under the BUILD Act, it's very important that the limitations in that organization, that prohibit the use of their funding for U.S. nuclear exports, be removed. That is something that Congress really needs to take a look at.

The CHAIRMAN. Dr. Peters?

Dr. PETERS. I agree with everything that Jeff alluded to.

From an authorization perspective I think the three—NEICA, NEIMA and now NELA—cover the landscape as I mentioned. Also, appropriations needs to follow as Jeff already said.

But I would also bring up—I think we've got to go do now. We've got to figure out, okay, so, it enables a public-private partnership but I think there's a lot of details that have to be worked out about what is the role of the government and what is the role of the private sector. And that's something—you've laid the authorization framework for that. I think now the agency, the department, the labs and the industry now need to go figure out what that looks like. And also, going and establishing the infrastructure to actually create the feedstock for high-assay, low-enriched uranium and actually fabricate fuel.

So I would say you've done your job. Now appropriations follows and now the community needs to come together and go do it.

The CHAIRMAN. Let me ask you, Dr. Peters. Your national lab is helping the Department of Energy work with DoD on the potential microreactor applications for military installations. This is something that we are looking at with great, great, great interest. Can you give me a little bit of update on how is this joint DOE/DoD program going and is there anything that we can do outside of passing NELA that would perhaps strengthen this partnership?

Dr. PETERS. Yeah, so DOE and DoD are actively communicating. DOE has appropriations from Energy and Water to work in the microreactor space. And so, that's being leveraged to work with DoD. I would say that it's working.

DoD had gone out with a request for information. That's filed with an RFP. There's multiple companies that have expressed interest that are pursuing it.

My lab and a couple other labs are actively involved with the proper controls and NDAs in place, working with a lot of those players. And every company that's pursuing the opportunity doesn't need the same thing, some need technical support, some need a site, some need fuel. So we're basically opening up our doors to whatever they need. But I would say it's moving along well. It always goes back to appropriations.

The CHAIRMAN. Right.

Dr. PETERS. On the DoD side as well.

The CHAIRMAN. Thank you for that.

Let me turn to Senator Manchin.

Senator MANCHIN. Dr. Peters, let's start with you again on this.

My concern is, as far as the world is going to be, I think, turning more to nuclear for—it's the quickest way to be carbon-free—and then carbon capture, utilization which Dr. Birol has talked about.

But my concern is with China and India and, as we commercialize this information, illicit proliferation may take place. I have reservations about how to best protect our intellectual properties as we do that. And as you know, we have had many concerns about that.

I would like to see what your thoughts are on how we balance our security and non-proliferation interests, in particular, U.S. intellectual property (IP), while exporting our U.S. nuclear technology and materials as we move forward developing a carbon-free world?

Dr. PETERS. Yes, sir. Thank you, Senator.

Well first, I would reemphasize the point that the way, an important way to establish U.S. leadership, and you heard that from Ashley, in particular, is that the ability to export U.S. technologies and know-how and regulatory framework and non-proliferation standards is an important part of our leadership. So, and it is a global market, as you know, so we're going to have to play in that global market. And to stay at the table, we have to be playing in that market.

However, I totally agree and the labs are actively working with DOE as we speak to protect not just the nuclear space but more broadly, economic security, battery technology, you name it, computing technology. And so, we're actively putting controls in place, working with DOE, the labs and DOE, to make sure that we're protecting it properly. And that's something that's, again, a very urgent, very important need and we're taking it very seriously.

But also, I would remind you also that the nuclear framework, the civil nuclear framework, is controlled very—by non-proliferation agreements we call 123 Agreements between countries. So if we're going to do business with a country, the U.S. does business with a country, it's controlled very strongly by those frameworks that we have in place with those countries.

So, there's this, it's a fine line we have to walk, sir, but we have to play in the global market in order to be a leader.

Senator MANCHIN. Thank you.

Mr. McManus, if you can talk to me about, as we grow older, we have an awful lot of people in all types of industries that are retiring and I think that Mr. Merrifield spoke about that also. Do you think we're going to have a challenge as far as having a workforce that is capable of meeting the growth of the advanced nuclear industry? I am going to talk with Ms. Finan next about how the environmental communities are looking toward decarbonizing and using carbon capture, sequestration, knowing the world is going to be using more fossil and nuclear as a way to decarbonize.

I am concerned about the workforce and if we are training them, having the ability to get up to speed quick enough to replace the projected retirements.

Mr. McMANUS. Yeah, it's an excellent question, Senator. And I think the United Association is not immune from the baby boomer generation exiting all industries of the United States.

I'm here to tell you proudly, we're 130 years old as of October. There's a lot of iconic businesses in America that haven't lasted 130 years, and right at this moment we have the largest workforce we've ever had in 130 years.

We've been growing for the last five years. We have 353,965 people growing at about 700 to 800 members a month. Active to retirees is a growing demographic that we look at through our pension funds, and we are continuing to lower the retiree to act. So we're a prosperous growing organization and that's due in part to national recruitment as well as our devotion to training, $220 million in private sector that I put in my public testimony that we spend on training.

We are also moving into virtual reality, augmented reality. We're reaching out to nationwide groups: Skills America, Women in the Trades from the national building trades, national high school and career counselors, vo-techs, for-profit welding schools, the Boy Scouts, the Girl Scouts. So we are continuing to reach out to each and every avenue and competing against a lot of industries in the United States and worldwide of what we can do.

But as we are sitting here right at this moment, we're meeting the needs. We have 1,500 UA members at Plant Vogtle which is a little bit of a remote spot in rural Georgia—Augusta, Georgia—and we've met every man power need that we need to make with commercial work and good work across the country as well too. So we have a very, very skilled workforce and a growing workforce.

Senator MANCHIN. Great.

Mr. MERRIFIELD. Senator, if I can just add?

Senator MANCHIN. Sure.

Mr. MERRIFIELD. I was a proud parent. My son went through the training program that Mike's folks have, and it was an excellent program. It really, they do a terrific job——

Senator MANCHIN. The apprenticeship?

Mr. MERRIFIELD. ——of preparing people for apprenticeships.

The other thing I would mention, you know, United also represents Canada and there are two major nuclear refurbishment programs in Canada at the Bruce and Darlington sites. The total of those two nuclear programs will be about $20 billion over the next ten years, and a significant number of folks from Mike's union will be involved in helping get those, keep those plants, nuclear plants online as well.

Senator MANCHIN. Thank you very much, Madam Chairman.

The CHAIRMAN. Thank you.

Senator Alexander.

Senator ALEXANDER. Thanks, Madam Chairman, and thanks to you and Senator Manchin for your leadership in this area and so many different ways and your participation on the appropriations process where you are a member as well.

You all have said, and I agree, if we don't do something soon nuclear power will not have a future in the United States. I was doing a little math, which I think I was pretty close, showing that nuclear is 60 percent of our carbon-free electricity, solar is 4, wind is 20. We know 12 reactors are closing. We would have to triple solar power and take up wind power by 50 percent to replace them.

Or let's look at it another way. We've got only 6 of our 90-plus reactors that have asked to extend for 20 more years. If half of them did for 20 more years, that would be the same thing as ten times the amount of solar power we have and doubling the wind power we have.

So it is pretty clear that is not going to happen. If we don't have nuclear, we know what will happen is we will have to rely on fossil fuels. It will be coal or natural gas, period. Wind and solar cannot replace it.

How do we know that? Well, we know other manufacturing countries in the world have had a similar experience. Germany cut in half its nuclear power, 25 to 12 percent. They had to replace it with coal and wind, and they have the highest electricity prices in the European Union which is not a good place to be if you are a manufacturing country in world competition and we are a manufacturing state in Tennessee. Or Japan, they have gone from 30 percent to 2 percent of their power nuclear. Their electricity prices are up 56 percent, and they are importing natural gas. So that is the problem, and the bill that Senator Murkowski is leading offers a solution.

I proposed a new Manhattan Project for clean energy with ten grand challenges for the next five years which would double our energy research funding which is about $6 billion through the Office of Science in the Department of Energy. And among the various challenges, natural gas, carbon capture, better buildings, better batteries—greener buildings, I meant—electric vehicles, cheaper solar, fusion, advanced computing, I put advanced reactors first.

So my question is a money question with a specific angle to it. How much are we talking about or who is going to tell us and when the kind of partnership that the Federal Government should engage in with the private sector to do that and wouldn't the long-term power purchase agreements be among the most important things we could do because we can, we are appropriating $100 million, $110 million I think, for advanced reactors, $100 million for small modular reactors?

So getting that number up to a direct appropriation that would be enough to fund two to five new advanced reactors by 2035 or one or two by five more years, is going to be a pretty heavy lift, except the long-term power purchase agreements by the government. Wouldn't that be the most useful way to encourage the private sector to spend a lot of money on advanced reactors? Mr. Peters or Ms. Korsnick?

Ms. KORSNICK. Yeah, I guess I'll start. Thank you, Senator, a good question and you're absolutely right with the statistics that you shared.

And I agree with you that the long-term power purchase agreements are a significant encouragement to build. They provide that revenue certainty for somebody that's building a large project going from the 10-year to the 40-year provision. And quite frankly, that makes the business case. And so, I think it's a huge step forward to go with the power purchase agreement.

Senator ALEXANDER. Well, the legislation, proposed legislation, says one or more power purchase agreements. Would you think it might say two or more or three or more to be more specific or am I heading down the wrong track there?

Ms. KORSNICK. Yeah, the more the better.

Senator ALEXANDER. Anyone else?

Dr. PETERS. Yeah, I would say to that last point, I would say as many as there are demonstrations because to me the demonstrations all need to have the ability to go into a PPA, a power purchase agreement, because I do agree with you, it will enable it.

Sir, as you well know, and I'm going to—each demonstration is in the small billions but that doesn't say it's all Federal Government outlay. The question that I raised earlier is the private sector and the public sector have to come together and come back to you with this is the model and this is cost estimate.

And we've looked at this enough to know that it's in that——

Senator ALEXANDER. I will conclude my comments because I am over time, but if we are spending $6 billion on energy research at the Department of Energy and advanced reactors and we are only spending $110 million on advanced reactors and $100 million on small reactors, getting to the small billions per advanced reactor is a pretty heavy lift for direct federal appropriation.

Dr. PETERS. Yes, sir.

Senator ALEXANDER. So I am looking for a way for the long-term power purchase agreement to provide sufficient incentive to the private sector to spend more of the money so that we are being realistic about the amount of money that we can appropriate through our appropriations.

Mr. MERRIFIELD. Senator, just very briefly.

I mean, I agree with Mark. I think it's got to be more than one. If you have just one, I think you get into the issue of the government picking winners and losers but I think a combination of government investment on a series of demonstration projects, on having the PPA program which is enormously valuable.

And I would note, you know, the wind and solar industry benefit enormously from investment in production tax credits. Having those tools available as part of the overall portfolio of tools for the deployment of advanced reactors will bring the private capital necessary to get these plants built.

The CHAIRMAN. Thank you, Senator Alexander, very important questions here for purposes of where we are right now.

Senator Heinrich.

Senator HEINRICH. Thank you, Chairman.

Mr. Merrifield, I want to go back to your testimony regarding Urenco USA. Obviously, that plant currently is the nation's only NRC-licensed commercial uranium enrichment facility. And you were talking about the need for HALEU. Do you think that Urenco's plant should be considered as a potential near-term option to provide HALEU for future advanced reactors?

Mr. MERRIFIELD. Certainly, it is among the places that should be used for that. They have the capability to expand their operations at that facility. Obviously, Urenco has a long and well-regarded role in providing enrichment services.

I would note the bill also conceptualizes the need for meeting the U.S. Government needs for these high enrichment and high enriched fuels. That is a capability that Urenco would not be able to——

Senator HEINRICH. Sure.

I am talking about specifically on the commercial market.

Mr. MERRIFIELD. Yeah, the commercial market, certainly that Urenco facility would be appropriate. I would note it would be important for the industry to have more than one source of that so it's not leaving us at risk.

Senator HEINRICH. Sure, right.

Ms. Korsnick, can you elaborate a little more on the issue you raised regarding second license renewals and, in your view, what are the safety bounds for license renewals and does that require statutory change?

Ms. KORSNICK. So, second license renewals are in process right now. Some plants have put in an application to the Nuclear Regulatory Commission. They did so last year. So it's in process right now with the NRC. We expect in the next year or so for them to pass judgment on those applications. There are no scientific reasons——

Senator HEINRICH. Those are 20-year extensions, is that correct?

Ms. KORSNICK. That's correct.

Senator HEINRICH. Okay.

Ms. KORSNICK. And there's no road block for that, it doesn't seem.

Senator HEINRICH. And a number of——

Mr. MERRIFIELD. Senator?

Senator HEINRICH. Yes——

Mr. MERRIFIELD. I was just going to say, I was a Commissioner in the NRC.

Senator HEINRICH. ——I will let you jump in in just a second.

You go ahead, and then I will add what I was going to add.

Mr. MERRIFIELD. I was just going to add, I was a Commissioner at the NRC when we did the first round of those license renewals. I think that there is no reason why virtually every U.S. reactor couldn't extend a further 20 years, and I think the NRC is putting in place a process and that could happen.

Senator HEINRICH. So that seems like an obvious place for where we could make a difference in terms of making sure we don't bring, take carbon-free energy offline.

I had another question there and I have just lost it, I apologize.

Ms. KORSNICK. That's okay. Let me just add to your point.

Senator HEINRICH. Yes.

Ms. KORSNICK. Conceptually, that makes a lot of sense. But if plants right now are being threatened in the marketplace, that's what shut those down.

Senator HEINRICH. That was exactly where I was going to go into. So a number of those plants who would be up for those renewals have chosen not to do so.

Ms. KORSNICK. That's correct.

Senator HEINRICH. That is a cost issue from what I understand. That is what I want to bring up for all of you to, sort of, jump into here is that it seems to me that the elephant in the room here and the thing that we have not talked about and the math that we have not talked about is price, both the price to create a new unit, and we are seeing prices like $9 billion in Georgia for a unit, and the price per kilowatt-hour. If you are talking about $.10 to $.14 a kilowatt-hour and you have gas at $.05 a kilowatt-hour and you have wind and solar at $.03 a kilowatt-hour, how are we going to drive down these costs because that seems to me to be an absolutely essential part of this formula if we are going to build new nuclear reactors.

Ms. KORSNICK. Yeah, so I would agree with you.

Obviously, we have to be able to create and build these plants in a cost-effective way. At the same token I would say that we have to look at the attributes that nuclear power is bringing to the marketplace to say that today those attributes are being provided for free.

And that's why the market is not recognizing, nuclear has hit a perfect storm of very low gas prices, other generation types that have significant subsidies and also a low, load growth profile right now in the United States. And if you take carbon out of the question, to your point, there's other sources that can be provided at a lower source.

Senator HEINRICH. For starters, we might want to value carbon-free energy across the board and make sure that there is some market mechanism to do that.

Ms. KORSNICK. That's correct.

Dr. FINAN. Senator, could I speak to your——

Senator HEINRICH. Yes, absolutely.

Dr. FINAN. On the new builds, in particular, I think a lot of the advanced reactors are really trying to address this key question, how do we address cost?

And we see two main approaches to reducing new build cost. We've come to understand that nuclear plants right now are mega projects——

Senator HEINRICH. Right.

Dr. FINAN. ——and mega projects are fundamentally vulnerable to delays.

Senator HEINRICH. And not scalable as you go down, not versus as you go up.

Dr. FINAN. Right, right. And there are just too many interdependencies. And so, you can either build up capacity to do mega projects and we've seen that elsewhere. Korea has a good capacity. We lost that in nuclear and we can work to rebuild that.

Another approach is to try to avoid being a mega project. And that's what a lot of the advanced companies are really trying to do is to increase the manufacturing and decrease the construction onsite. And that will also make them more of a U.S. export because you can do that manufacturing in the United States, even if you're shipping it to Poland. Whereas, you're not going to export an entire construction team to Poland.

So there are a lot of reasons to take that approach and those are two ways to address the upfront cost.

Senator HEINRICH. Thank you, Chairman.

The CHAIRMAN. Thank you, Senator Heinrich.

Senator McSally.

Senator MCSALLY. Thank you, Chairwoman. I appreciate you having this important hearing today.

The Palo Verde generating station in Arizona is the largest electricity generating plant of any source in the United States averaging 3.3 gigawatts. In three reactors, Palo Verde produces more than one-third of the electricity in my state. The plant provides carbon-free power to more than four million people across the Southwest including Phoenix, Tucson, Los Angeles, San Diego and more.

According to Arizona Public Service, which is the main operator of Palo Verde, the amount of clean air power produced at this site has offset the emissions of nearly 484 million tons of carbon dioxide. That is the equivalent of taking 84 million cars off the road for a year. To generate this much clean electricity from solar power you would need almost 200 square miles of solar panels or roughly the land mass of the entire city of Scottsdale, Arizona.

Now I am a strong supporter of solar and wind power but these technologies do have their limits, especially when it comes to meeting industrial power needs and providing electricity in adverse weather and at night, for example.

But in addition to being an engineering marvel due to its size, Palo Verde is also remarkable for its water efficiency. In the heart of one of North America's largest and driest deserts, Palo Verde is the only nuclear power plant in the country not built near a large body of water. Instead, it recycles more than 20 billion gallons of wastewater from surrounding municipalities to cool the plant.

Palo Verde has often led American nuclear power plants in efficiency, operating at 90 percent full capacity while providing competitively priced electricity.

While much of the conversation today is focused on future technology and the promise of advanced nuclear reactors which we need, it is clear the nation's existing fleet of nuclear reactors, as many of you have talked about, play a critical role in providing safe, reliable, clean electricity to power our homes and our economy.

So any serious conversation we have about carbon reduction goals needs to include robust support for our nation's existing nuclear power plants, in my view, as many of you have also shared.

Combined with other renewables and more efficient use of natural gas and traditional fossil fuels, we really can have a leadership in a true all-of-the-above energy strategy which I support.

I just wanted to lead in with that. We are very proud to have Palo Verde in Arizona.

Ms. Korsnick, you talked about the existing fleet of nuclear power plants in your testimony and in other questions as a central part of our critical infrastructure needs. Can you expand on the importance of these large nuclear generating stations like Palo Verde and in meeting our current and our future energy needs?

Ms. KORSNICK. Absolutely. I'm very proud of the United States' nuclear fleet. Last year we operated at a 92 percent capacity factor, actually a little bit larger than that, capacity factor meaning operating as many hours as you can.

But if you look over the last 15-plus years, the U.S. fleet has had a greater than 90 percent capacity factor. You don't get that way by being lucky. You get that way because we are very, very good and I would say, world's best, at operating nuclear power plants. And we've done that through really understanding operational excellence, rigorous training programs akin to the training programs that Mark McManus mentioned earlier. And we should be very proud of the operational excellence that we have here in the United States.

That's why it's so important that we are involved in building these plants outside of the United States. These aren't just widgets. You don't just send them around. It's not just the hardware, it's the how do you operate these and to make sure that these are done with operational excellence.

I used to be an operator. I worked in the control room. I'm very personally familiar with the training programs. It's very rigorous. Something we should be very proud of here in the United States.

Mr. MERRIFIELD. Senator, I would just add.

Senator MCSALLY. Yes.

Mr. MERRIFIELD. I agree, completely agree, with everything Maria just said.

When I was an NRC Commissioner, I got a chance to go to over half of the world's 440 nuclear power plants. And I can attest I made multiple visits to Palo Verde. You have as fine a nuclear power plant in Arizona as anywhere around the world.

Senator MCSALLY. Amen. Thank you, sir.

A lot of discussion today and often is about, obviously, reducing our carbon emissions and this has been part of the discussion already. You know, it is frustrating because, I mean, again, we support solar and wind but sometimes nuclear is just left out of the conversation by some people when they are thinking about clean energy.

We had an out of state billionaire come into Arizona last year on an initiative trying to tell us exactly what kind of energy we needed and they conveniently left out nuclear as part of what the goals would have been.

So can you talk about how important it is, as we are trying to meet carbon emissions, that nuclear is a part of that clean energy conversation? If anybody wants to jump in?

Mr. MERRIFIELD. Senator, you are spot-on in that regard. As was demonstrated, and I think Senator Alexander spoke of this, those countries like Germany which have taken nuclear assets offline have seen actually a spike in their carbon production.

There is one thing I think is important though and this is coming from the energy organization in North Carolina and South Carolina of which I am a part. We believe in all-in. And I do believe that wind and solar, like you do, play a very important part there. I think for the purposes of the advanced reactors, which is a major focus of this hearing today, many of these are complementary.

Senator MCSALLY. Exactly.

Mr. MERRIFIELD. It's not nuclear or wind and solar. It's really how do those work together to provide the carbon-free energy that we need.

Senator MCSALLY. Exactly.

Mr. MERRIFIELD. And many of those designs going forward are designed to load follow, to work in a way which would be very well interconnected with wind and solar assets.

Senator MCSALLY. Exactly.

Mr. MERRIFIELD. So I think it is important for both going forward.

Senator MCSALLY. I totally agree. Thanks.

I am out of time. I appreciate it.

The CHAIRMAN. Thank you, Senator McSally.

Senator King.

Senator KING. I apologize for not being here for the entire hearing. I was at an Armed Services Committee hearing, but has the word waste been mentioned in this conversation? I don't think it has.

I just met with a group of young people. They are all for carbon-free energy. They are excited, but they are not excited about paying the price of our using electricity and leaving to them what to do with the waste.

We have not met a 70-year promise in this country yet on nuclear waste. I have a high-level nuclear waste site in Westport Island, Maine, because when Maine Yankee closed, the Department of Energy breached its contractual obligation to take away that waste and do something with it. So that is my problem with this bill. I am not opposed to the technology of nuclear power. I am definitely in favor of carbon-free power. I think it can be an enormous boon to our economy and to our climate. But I just don't know how we have this discussion and not talk about this really significant problem that is not being addressed. And I am tired of passing burdens on to our children. I don't think that is what we are sent here to do.

Mr. Commissioner?

Mr. MERRIFIELD. Senator, I look at this, I think we have a public policy problem. There are a variety of different technical methods to actually safely address long-term waste.

Senator KING. Yes, but they have not been implemented in 70 years.

Mr. MERRIFIELD. Well, there are a variety of them. They are on the table right now.

Now obviously, Congress will decide what it wants to do or not do relative to Yucca Mountain, but there are also waste facilities, intermediate waste facilities, proposed in New Mexico and Texas that can take that fuel off of the site. I mean, Yankee, and I have visited that beautiful site. There's also a technology called deep isolation that talks about using——

Senator KING. You are talking about future technologies and proposed projects.

Mr. MERRIFIELD. These are currently available.

Senator KING. We are talking about a bill here to promote nuclear power——

Mr. MERRIFIELD. Right.

Senator KING. ——without having solved that problem. I think we have it backward. Let's solve the waste problem and then talk about promoting nuclear power. What am I missing?

Mr. MERRIFIELD. Well Senator, those capabilities are available now.

Senator KING. They are not in place.

Mr. MERRIFIELD. It's been demonstrated in Finland where they are putting in a deep geologic repository in granite. Those technologies are demonstrated and capable.

We have a public policy problem that Congress needs to address.

Senator KING. But we are not doing them. We are not doing them.

Anybody else want to tackle this?

Ms. KORSNICK. Yeah, I mean, I would agree with you, we need a solution to the waste problem. It's not a technical problem. It's something that needs to be addressed in these halls, and I know that there are folks that are focused on doing that.

At the same token, I think you have to look at the benefits that this technology provides. As an industry, we've contributed $40 billion to be a part of the solution to this waste issue. So we've contributed the money.

Senator KING. Oh, I agree, you have been—you have paid a lot of money that you have not gotten anything back for. The industry, Maine Yankee in Maine is, I don't know, $70 or $80 million, a lot of money.

I just think as part of this bill there ought to be a section that talks about solving the waste problem.

Let's be clear. This bill, which I think is a good bill, will promote additional nuclear power. But it says nothing about solving this fundamental problem that has been with us for 70 years. This government has been promising the American people that they are going to solve this problem, and they haven't.

So I don't——

The CHAIRMAN. Senator King, I don't mean to interrupt on your time. I will give you more time here.

But I did mention in my opening statement that the bipartisan measure that Senator Alexander and Senator Feinstein and I have been working on for several Congresses now that deals directly to the waste issue, we have introduced that today. We would encourage you to join us on that.

But we do recognize——

Senator KING. Subject to reading it, the answer is yes.

[Laughter.]

The CHAIRMAN. Subject to reading it, of course, of course. That is what we always say.

But I think that your point is clearly a fair one. What we're doing with NELA is focusing on that future for nuclear but we do recognize that we have this responsibility to address the waste side of it.

Senator KING. Thank you.

The CHAIRMAN. We are proposing that in that separate legislation.

Senator KING. That is very helpful. Let me——

The CHAIRMAN. I will give you back your 40 seconds.

Senator KING. No, it says a minute and 19. I got a dividend, I guess.

I couldn't help but notice when you are talking about the long-term PPA, you are talking about a high capital cost, low operating cost and shorter-term contracts.

I used to be in the hydro business. Almost all those same arguments apply to hydro. And we have not had much in the way of hydro development in the country, in part, because of short-term PPAs that cannot amortize the high capital cost. I just make that as an observation. I fully understand that business.

One question, and this is a genuine question that I don't know the answer to. Operating costs, what is the comparative operating cost of a nuclear plant compared with gas, coal, hydro? I think that is a relevant question here. We know that it is relatively low, but I would like some figures, perhaps you can share some.

Ms. KORSNICK. Sure, we look as an average across the whole industry last year that operating cost was 3.1 cents a kilowatt-hour.

Senator KING. Okay, so that is the ongoing operating cost. Does that include fuel?

Ms. KORSNICK. Yes, that's capital fuel and O&M.

Senator KING. Oh, that's capital as well.

I am talking about just O&M, obviously something less than 3.1.

Ms. KORSNICK. That's correct.

Senator KING. Okay.

Well, the other piece, of course, which we have talked about at some length, and I am out of time, is cost and that is what we really have to work on.

I believe that we should be paying insurance policies for getting out of the fossil fuel business. The question is how high is the premium? And that is where this industry, I think, has a contribution to make, but a ways to go.

Thank you very much, Madam Chair. Thank you for introducing this bill.

Mr. MCMANUS. If I may, Madam Chairman?

The CHAIRMAN. Mr. McManus.

Mr. MCMANUS. You know, I think the question—I never like to answer a question with a question. What is the cost of not doing anything on subsidizing or enhancing the nuclear fleet? If we have 20 percent of America's power and we pull that off the table, what's the cost of the climate change, to the young folks, saying that we may have this backward.

I disagree on that. I think Congress, and sometimes it's hard to say this to Congress, we can do more than one thing at a time. I think we can work on the waste as we're not pulling off 98 more nuclear fleets.

And then the economic cost as well is when up in Maine, Yankee Maine, when a nuclear facility comes offline and pulls on, it devastates communities. The economics that aren't measured is the local economics of the people, the workers, the auxiliary businesses that make up the communities that these fleets are there.

If you talk to folks that are in communities with 98 nuclear power plants, they like the nuclear power plants there. They like the economic engine that it brings to it.

Thank you.

Ms. KORSNICK. Sir, if I could just answer your question? I pulled up my information. If you just look at the operational cost it's 1.97 cents a kilowatt-hour.

Senator KING. That is helpful, I appreciate it.

The CHAIRMAN. Thank you, Senator King.

Senator Cortez Masto.

Senator CORTEZ MASTO. Thank you. I appreciate the conversation today as well as with this bill.

Let me just say, with all due respect, the bill that you talked about that you dropped earlier today still identifies Yucca Mountain as a site and does not give the State of Nevada consent-based siting. And that is why I disagree with it.

If all the states were treated equally when we are looking at deep geologic storage, that is one thing but still we have, I think, a policy moving forward that is not based on sound science for the very reason that you said, a lot of these deep geologic sites are in granite. Yucca Mountain is not granite. It is volcanic.

And so, but let me get to the question I think that my colleague also asked, this was a concern of mine. I think we should have been addressing this over the last 20 years is what do we do with this waste?

And what I am hearing is that this legislation as it tackles advanced nuclear reactor technologies and, I think, Dr. Finan, you addressed this, is that part of the benefits of advanced nuclear reactor technologies is the reduction in nuclear waste. Can you address that specifically?

Dr. FINAN. Sure, I mean, I think that I want to just say that I appreciate the question and that the waste issue is really important. For nuclear to contribute to carbon reductions to the extent that it's capable, we have to address this waste issue.

Advanced nuclear reactors can reduce the nuclear waste quantity and the length of time that it needs to be managed. But we will still need, ultimately, to come to a policy that has broad support and is sustainable because we've been managing waste for a long time. And I think that the nuclear industry actually manages its waste better than any other. We track it. We store it. We package it. We watch it. We keep track of it. I mean, it's really, we do a lot of managing. But we don't have a long-term strategy. So, I think it's time to take a hard look at our technological options and at our process and commit to finding a strategy.

Senator CORTEZ MASTO. Oh, I agree. I agree with that on the policy. And I think that is what we should have been doing the last 20 years. We have wasted time and money.

But my question to you is this bill, and what I am told this bill's, this focus, this advanced nuclear reactor technology that we are all want to invest in and do the R&D and move toward, is to reduce, it has the benefit of reducing nuclear waste. Can you give me specifics on that and how it reduces it? I would open it up for anybody else as well to talk about it.

Dr. PETERS. To put it succinctly, the reason you go to the higher enrichment, we've talked about HALEU, high-assay, low-enriched uranium, you push the enrichments up, is partly because you want to go small, to even very small, but also because you can generate more unit energy per amount of fuel. So you're using less fuel to get the same amount of energy where you can generate more energy out of the fuel. So you're minimizing the amount of spent fuel that has to be managed.

Some of the reactor technologies could also, in theory, if one chose, could actually use that material as fuel and even recycle the material.

Ms. KORSNICK. Yeah, I think that's really the point that we're making to you without going into a lot of, you know, sort of, nuclear engineering specifics.

Senator CORTEZ MASTO. Right.

Ms. KORSNICK. The kind of fuel that these units use that we're calling waste is really just transformed. It has taken what was U2–35 and it's made it something else. It's made it some into plutonium. It's made it some into U2–38. These advanced reactors, they use that kind of fuel.

So really what we're creating is, what you call today as waste, is future nuclear fuel. And now we're building reactors that can use that future nuclear fuel.

Senator CORTEZ MASTO. Thank you.

My next question then is this Senate bill 903, this bill, is it focused specifically on incentivizing and supporting advanced nuclear technology or does the existing nuclear fleet that we have get to take advantage of some of the amendments and language in here like extending the purchase power agreements, the pilot projects? Does our existing fleet get to take advantage of Section 903 as well?

Dr. PETERS. This legislation is specifically focused on advanced reactors.

Senator CORTEZ MASTO. So what I am hearing right now is our existing fleet of nuclear reactors cannot benefit at all from Section 90, from the Senate bill 903?

Ms. KORSNICK. Well, I would just take one exception to that. The HALEU provision for this, there are some of the current fleet that would like to use some of the higher enrichment. What that allows them to do is operate a longer period of time which enables them to reduce some cost. So there is some benefit for them through the HALEU.

Mr. MERRIFIELD. Right. Maria is quite right in mentioning that. Lightbridge Corporation, along with Framatome, is developing a metallic fuel that would utilize HALEU in order to produce a fuel for the current fleet that would allow both higher utilization of those facilities. It may also allow them to increase their power to make them even more efficient. So in that regard, yeah, the bill does include language in here would be helpful in that regard.

Senator CORTEZ MASTO. Okay.

Dr. FINAN. And Senator, could I just add that extension of the Federal Power Purchase Agreement term can benefit all technologies? That's technology neutral, so it could benefit nuclear technologies. It could benefit geothermal, solar and wind. And I think that's an important aspect of the bill.

Senator CORTEZ MASTO. Thank you. Thank you very much.

The CHAIRMAN. Thank you, Senator Cortez Masto.

And just to your point about our waste bill that has been referenced now a couple times and, again, I would urge you to look critically at it because our purpose, our intent in moving forward is to address a mechanism that will allow for a consent-based process for these consolidated storage facilities.

It doesn't take Yucca off the table if it were to be determined that the folks there seek to endorse this. But our approach, and I am going to turn to Senator Alexander, we have both been working on this for so many years here, but again, where there is a recognition that we have to get started. We have been hung up for a long time on Yucca. You know that. We know that. But in the meantime, our approach has been to figure out how we can move forward, consent-based, and help address some of the stalemate that we have seen.

Senator Alexander.

Senator ALEXANDER. If I could just take a couple of minutes.

Starting with Senator King, the Murkowski bill which a number of us support, Senator Feinstein, others, has nothing to do with Yucca Mountain. What it does is it creates other sites. It authorizes interim storage sites which we have passed and approved in our energy and water appropriations bill with the consent of the Ranking Members of this Committee, two or three times now. It does the same thing with private sites which are probably the fastest way to get waste out of Maine or California or where ever else to another place.

There are two applications for private sites in New Mexico and Texas. It authorizes a separate long-term site, a second, if you will, Yucca Mountain. But it does not do anything about Yucca Mountain. I would hope that both Senators would look carefully at the legislation.

We can argue about Yucca Mountain, but this bill does not have anything to do with Yucca Mountain because it provides additional sites and the only reason we haven't—Senator King was asking wonderful questions about why all these technologies that are available haven't been used. It is our fault. It is the fault of the Congress over the last 35 years.

We have not approved any of it because we have had a stalemate with the House of Representatives. We will pass our provision that says let's go forward with these alternative sites then the House says, we won't do that unless Yucca Mountain is included and we come to a stalemate.

So I wanted to characterize Senator Murkowski's bill in that way in hopes that it would have broader support.

Senator CORTEZ MASTO. Can I ask a point of clarification because I have read the bill, and I appreciate you both being here as the sponsors of the bill and I am trying to understand as well.

So the consent-based siting that is in there gives every state consent-based siting but Nevada over—because if Nevada is unhappy with consent-based siting, with respect to Yucca Mountain, we don't have that authority to stop it. We don't get that.

Senator ALEXANDER. It does not have anything to do with Yucca Mountain.

Senator CORTEZ MASTO. So Yucca Mountain is not in your bill at all?

Senator ALEXANDER. No.

Senator CORTEZ MASTO. It is taken out completely?

The CHAIRMAN. It does not reference it.

Senator ALEXANDER. Yucca Mountain is not a part of the bill, correct?

This is about additional sites other than Yucca Mountain. In fact, if you are opposed to Yucca Mountain, which I gather you are, I would encourage this bill because it creates other sites to take used nuclear fuel from Maine and California and have a place to put them.

Senator CORTEZ MASTO. The last, when it was dropped last time it had Yucca in it. So I appreciate it if Yucca is not in this time, I will absolutely take a look.

So just for clarification, Nevada does have the ability to engage in consent-based siting as well like every other state?

The CHAIRMAN. Like every other state.

Senator ALEXANDER. Madam Chairman, if I may say, this bill says nothing about Yucca Mountain.

Senator CORTEZ MASTO. Okay.

Senator ALEXANDER. It does not change the law. There's a 30-, 40-year history of Nevada being involved in approving and not approving Yucca Mountain which I don't think it helps to get into today.

Senator CORTEZ MASTO. Yes, that is great to hear.

Senator ALEXANDER. We tried to avoid that. It leaves Yucca Mountain right where it is. I think we should have a vote on Yucca Mountain—and I will vote for it and you will vote against it—and we will see who has the most votes. But in the meantime, we ought to go forward.

Senator MANCHIN. If I could say one thing.

My understanding was this. Yucca will not be taken off the table, but Yucca will not be ahead of anything else until we get everyone else evaluated to Yucca's standard because so much effort has been toward Yucca over the years. So, it is where it is. People made up their mind.

Senator CORTEZ MASTO. So nothing is going to happen with Yucca until we survey every other site for deep geologic storage.

Senator MANCHIN. That is my intention. That is what my understanding is.

Senator CORTEZ MASTO. And so, it will be on hold until we do the survey for every other potential opportunity?

Senator MANCHIN. I think we should evaluate all the other sites that are on the table and other sites that should be evaluated before anything is moved forward, so Yucca just is not all by itself.

The CHAIRMAN. Right.

I am just reminded, Yucca is in law, if you will. We have some years back made that determination.

It is not, certainly my intent, as one of the authors of this, that the State of Nevada is treated any differently when it comes to what we are looking to build out which is this consent-based storage. And so, Nevada would be treated the same there.

We do not reference Yucca, but I think to your point, it may be inferred that Yucca is treated differently because of the existing law. So know that my intent is to make sure that what we are doing here is we are allowing for a process to move forward so we can address the waste issues. We have to resolve Yucca, one way or another.

In the meantime, everything has been put on pause. Everything has been put on pause for decades now and we have not been able to do anything. We argue over Yucca, and we cannot get moving on anything else. So this is, kind of, an opportunity for us to get moving while we make a determination as to whether or not Yucca is in the future or not.

Senator ALEXANDER. Madam Chairman?

The CHAIRMAN. Yes.

Senator ALEXANDER. If I could suggest, to eliminate any confusion about this bill that you sponsor and I cosponsor, maybe a hearing at some point——

The CHAIRMAN. Yes.

Senator ALEXANDER. ——to make, on this topic, to make it clear the relationship this bill has to Yucca Mountain or not would be useful so we do not have confusion about it.

The CHAIRMAN. Well, as I mentioned, we are just dropping this bill today. This will give everybody a chance to really, keenly eyeball it.

I think Senator Alexander's suggestion is a good one. We all recognize that if there is going to be this vibrant future for nuclear, whether we are talking the more traditional existing or the advanced or the microreactors, we have to address waste. So know that this Committee is keenly focused on that.

Now I am going to turn to Senator Cantwell, who has been living with it in her state for far too many years, and we know we have to address Hanford and the other sites.

Senator Cantwell.

Senator CANTWELL. Thank you, Madam Chair, and thank you for that intro because as you and our other colleague who is leaving are both appropriators, I do want to remind us of the ongoing challenges of cleaning up nuclear waste at the Hanford site.

I was just out there last week and saw some progress on low-level waste, but we clearly need to keep making progress and need a budget that reflects making milestones. So thank you for bringing that up.

I wanted to ask the witnesses, if I could, kind of a twofold question, one on the front end of where we are today and one on the back end of where we need to go. The front end being what do we do on the IP side if the United States is going to continue to be a leader in the development of next generation technologies, what can we do to do IP protection on the national security side so that we are developing a market, not just for the United States, but for other countries? And you know, to me, if we are going to be an important player in this, we have to figure out how to get this IP protected and not have it used. So I want to ask that question.

The back end question is what do we need to do on material sciences? We are doing a good job at PNNL on some aspects of this, but don't we need to do more on material sciences for various nuclear technology applications and what should we be doing?

So I will throw that open to you.

Mr. MERRIFIELD. Senator, if I can first take a crack at the IP issue?

And I certainly understand the concern of members of this Committee in that regard, you know, as an attorney and one that counsels many advanced reactor developers, we're not, on my client's behalf, we aren't seeing a lot of issues with the current structure of intellectual property here in the United States. I think we're a little bit cautious that they're not—recognizing that there are issues of enforcement and issues of national security and the whole issue of theft of some of the technology. Westinghouse is obviously in the minds of many.

We have an existing structure in the United States that's actually working quite well, and to tighten down intellectual property further could hinder the ability of U.S. companies to export these technologies and would only allow the Chinese, the Russians and others to take a larger share of the marketplace.

Senator CANTWELL. Well, some exports are getting shut down now, so, that is why I am asking. We have to figure out how to accomplish being a player in next generation technology and protecting its IP.

Dr. PETERS. Yeah, Senator Cantwell, Senator Manchin asked us a somewhat similar question earlier and from the labs' perspective, I am at Idaho National Laboratory, but the labs are all working with the Department of Energy right now on that exact question about how to make sure we're protecting the wide spectrum of energy technologies, recognizing that it's a global market. And if the U.S. is going to lead, we're going to have to plan that global market, as Jeff alludes to, but also making sure we have the proper controls in place, particularly as technologies get closer to market.

Basic science probably needs to be more open, very basic science, but then when you get closer to technologies that go to market, we need to have more controls. And we're actively working with DOE on how to figure out how to protect the U.S. interests in that space.

Senator CANTWELL. What else do we have to do that we are identifying that DOE's role would be?

Dr. PETERS. I would encourage the Congress to understand better what DOE is doing, because DOE is very actively working with the labs and the universities in this space as we speak. The lab directors are personally all involved in the conversations.

So I would say before Congress——

Senator CANTWELL. My guess is we know detection because that is why we have been able to detect that it has been used for other purposes, but now we have shut down markets. So we have to figure out how to—I am just pointing out we are going to have this discussion——

Dr. PETERS. Yes.

Senator CANTWELL. ——and we think that international market is a big place. We have to figure out, like in every aspect of intellectual property, how we are going to make sure it is protected.

Dr. PETERS. Yes. And I was just trying to make the point that it's already being taken seriously. So, I think a good conversation would be helpful.

Senator CANTWELL. With DOE?

Dr. PETERS. Yes.

Senator CANTWELL. Great.

And then what about, yes, on the——

Dr. PETERS. If it's okay, I'll say on for material science, if that's okay.

Senator CANTWELL. We like northwest labs.

Dr. PETERS. Yeah, yeah, right and they're a close collaborator in the nuclear space with us.

So a lot of these advanced systems, really, it's about materials. It's about advanced fuels, new kinds of fuels. It's about new kinds of structural materials that can last longer.

And so, there's a lot of science that's going into, the labs and universities are doing a lot the foundational science that will enable those advanced materials. So, that's using all the user facilities at the laboratories, the computer capability, the laboratories, across the board. So, yeah, I would say it's all about materials. And so, the labs have a really, really key role.

Senator CANTWELL. Do we need more investment there or targeting these applications?

Dr. PETERS. I think we need more focused investment to make sure that we're getting—and that's, sort of, what NELA is about, right—focused investment to get to demonstrations. I don't think this needs to be a broad sort of scientific sandbox, if I may, but a very focused investment in the right materials.

Mr. MERRIFIELD. Senator, in terms of investment, one thing I would add and I agree with Mark. When you look at the cost of building any of these power plants, about half of the cost is associated with action in the engineering and construction. So as we're looking at trying to move these forward, advanced construction is also an area of investment that we really need to be thinking about.

Senator CANTWELL. Okay, thank you.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator.

I appreciate the conversation this morning. I think it has been good, it has been helpful as we look to the attributes of NELA and how we can continue to build on some of the legislation that we have introduced and passed previously.

It is also a good reminder to us that we must address the issue of the nuclear waste end of it and how we are able to do that. We are going to need the help and the cooperation of others as we are talking about the technologies of the future. We also have to realize that we have a legacy of the past that must be addressed. So we have a lot to work on within this Committee.

I will tell you, I get really excited about the prospects for leadership here in this country again when it comes to nuclear. Several of you have mentioned that the one thing that we do best here is on the innovation side. It is moving forward with these technologies.

I love the idea that not only are we going to be moving us in a direction that will help us from an emissions perspective, but also this is exportable, this technology, the manufacturing that we would be capable of. This can help us not only from the jobs perspective which you point out, Mr. McManus, but again, as we deal with other countries that are also looking for those solutions.

I was in Vietnam over this past recess and you have a country there that their economy is just booming and they are seeking those cleaner energy, those lower emission solutions. It was really interesting that as they talked about incorporating more wind and solar and were eyeing the prospects of LNG, their reality is that they are continuing to aggressively use coal and that nuclear is not part of their conversation. How we can help change that view and that perspective, I think, comes with the technology.

I am really excited about the opportunity for the small, small, the microreactors. We have opportunities in a state like mine where it is not only remote, it is really, really remote. And yet, these are areas where there is potential for access of certain minerals that are going to be key to our nation's, just, stability when it comes to being able to access rare earths and certain critical minerals. But if you can't get power to them beyond diesel power generation, it is pretty darn expensive, to make this mine work. So I look at the application of microreactors for that purpose as extraordinarily important.

I am excited about what we can do with the application for creating hydrogen or desalination of water. I think that that is something that, particularly as we look up north on the North Slope and how, again, you are going to need water for your various applications in the oil and gas industry up there. How about powering it with zero emission technology that allows for you to desalinate your water and process things cleaner and just more efficient?

So I am excited about that. I think that we are moving in the right direction. And it is through leadership that we see from so many of you and the organizations that you represent. We greatly appreciate the work of our national labs in this space.

But when we are talking about how we lead in energy innovation, when we are talking about our potential within the nuclear space, I thank you for what you are contributing to it.

We are going to work on moving NELA. Help us with that. It is a good, strong, bipartisan bill but around here legislating seems to get harder and harder every day but we have demonstrated out of this Committee that we have great capacity for that and know that that is exactly what we intend to do.

With that, I thank those of you who have come and provided such good, strong testimony.

The Committee stands adjourned.

[Whereupon, at 11:50 a.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

II

116TH CONGRESS
1ST SESSION

S. 903

To direct the Secretary of Energy to establish advanced nuclear goals, provide for a versatile, reactor-based fast neutron source, make available high-assay, low-enriched uranium for research, development, and demonstration of advanced nuclear reactor concepts, and for other purposes.

IN THE SENATE OF THE UNITED STATES

MARCH 27, 2019

Ms. MURKOWSKI (for herself, Mr. BOOKER, Mr. ALEXANDER, Mr. MANCHIN, Mr. RISCH, Mr. WHITEHOUSE, Mr. CRAPO, Mr. COONS, Mrs. CAPITO, Ms. DUCKWORTH, Mr. SULLIVAN, Mr. BENNET, Mr. GRAHAM, Mr. PORTMAN, and Mr. GARDNER) introduced the following bill; which was read twice and referred to the Committee on Energy and Natural Resources

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A BILL

To direct the Secretary of Energy to establish advanced nuclear goals, provide for a versatile, reactor-based fast neutron source, make available high-assay, low-enriched uranium for research, development, and demonstration of advanced nuclear reactor concepts, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Nuclear Energy Leadership Act".

SEC. 2. AUTHORIZATION OF LONG-TERM POWER PURCHASE AGREEMENTS.

Section 501(b)(1) of title 40, United States Code, is amended by striking subparagraph (B) and inserting the following:

"(B) PUBLIC UTILITY CONTRACTS.—

"(i) TERM.—

"(I) IN GENERAL.—A contract under this paragraph to purchase electricity from a public utility may be for a period of not more than 40 years.

"(II) OTHER PUBLIC UTILITY SERVICES.—A contract under this paragraph for a public utility service other than a service described in subclause (I) may be for a period of not more than 10 years.

"(ii) COSTS.—The cost of a contract under this paragraph for any fiscal year may be paid from the appropriations for that fiscal year.".

SEC. 3. LONG-TERM NUCLEAR POWER PURCHASE AGREEMENT PILOT PROGRAM.

(a) IN GENERAL.—Subtitle B of title VI of the Energy Policy Act of 2005 (Public Law 109–58; 119 Stat. 782) is amended by adding at the end the following:

"SEC. 640. LONG-TERM NUCLEAR POWER PURCHASE AGREEMENT PILOT PROGRAM.

"(a) ESTABLISHMENT.—The Secretary shall establish a pilot program for a long-term power purchase agreement.

"(b) REQUIREMENTS.—In developing the pilot program under this section, the Secretary shall—

"(1) consult and coordinate with the heads of other Federal departments and agencies that may benefit from purchasing nuclear power for a period of longer than 10 years, including—

"(A) the Secretary of Defense; and

"(B) the Secretary of Homeland Security; and

"(2) not later than December 31, 2023, enter into at least 1 agreement to purchase power from a commercial nuclear reactor that receives a license from the Nuclear Regulatory Commission after January 1, 2019.

"(c) FACTORS FOR CONSIDERATION.—

"(1) IN GENERAL.—In carrying out this section, the Secretary shall give special consideration to power purchase agreements for first-of-a-kind or early deployment nuclear technologies that can provide reliable and resilient power to high-value assets for national security purposes or other purposes as the Secretary determines to be in the national interest, especially in remote off-grid scenarios or grid-connected scenarios that can provide capabilities commonly known as 'islanding power capabilities' during an emergency scenario.

"(2) EFFECT ON RATES.—An agreement to purchase power under this section may be at a rate that is higher than the average market rate, if the agreement fulfills an applicable consideration described in paragraph (1).".

(b) TABLE OF CONTENTS.—The table of contents of the Energy Policy Act of 2005 (Public Law 109–58; 119 Stat. 594) is amended by inserting after the item relating to section 639 the following:

"Sec. 640. Long-term nuclear power purchase agreement pilot program.".

SEC. 4. ADVANCED NUCLEAR REACTOR RESEARCH AND DEVELOPMENT GOALS.

(a) IN GENERAL.—Subtitle E of title IX of the Energy Policy Act of 2005 (42 U.S.C. 16271 et seq.) is amended by adding at the end the following:

"SEC. 959A. ADVANCED NUCLEAR REACTOR RESEARCH AND DEVELOPMENT GOALS.

"(a) DEFINITIONS.—In this section:

"(1) ADVANCED NUCLEAR REACTOR.—The term 'advanced nuclear reactor' means—

"(A) a nuclear fission reactor, including a prototype plant (as defined in sections 50.2 and 52.1 of title 10, Code of Federal Regulations (or successor regulations)), with significant improvements compared to the most recent generation of fission reactors, including improvements such as—

"(i) additional inherent safety features;

"(ii) lower waste yields;

"(iii) improved fuel performance;

"(iv) increased tolerance to loss of fuel cooling;

"(v) enhanced reliability;

"(vi) increased proliferation resistance;

"(vii) increased thermal efficiency;

"(viii) reduced consumption of cooling water;

"(ix) the ability to integrate into electric applications and nonelectric applications;

"(x) modular sizes to allow for deployment that corresponds with the demand for electricity; or

"(xi) operational flexibility to respond to changes in demand for electricity and to complement integration with intermittent renewable energy; and

"(B) a fusion reactor.

"(2) DEMONSTRATION PROJECT.—The term 'demonstration project' means an advanced nuclear reactor operated—

"(A) as part of the power generation facilities of an electric utility system; or

"(B) in any other manner for the purpose of demonstrating the suitability for commercial application of the advanced nuclear reactor.

"(b) PURPOSE.—The purpose of this section is to direct the Secretary, as soon as practicable after the date of enactment of this section, to advance the research and development of domestic advanced, affordable, and clean nuclear energy by—

"(1) demonstrating different advanced nuclear reactor technologies that could be used by the private sector to produce—

"(A) emission-free power at a levelized cost of electricity of $60 per megawatt-hour or less;

"(B) heat for community heating, industrial purposes, or synthetic fuel production;

"(C) remote or off-grid energy supply; or

"(D) backup or mission-critical power supplies;

"(2) developing subgoals for nuclear energy research programs that would accomplish the goals of the demonstration projects carried out under subsection (c);

"(3) identifying research areas that the private sector is unable or unwilling to undertake due to the cost of, or risks associated with, the research; and

"(4) facilitating the access of the private sector—

"(A) to Federal research facilities and personnel; and

"(B) to the results of research relating to civil nuclear technology funded by the Federal Government.

"(c) DEMONSTRATION PROJECTS.—

"(1) IN GENERAL.—The Secretary shall, to the maximum extent practicable—

"(A) complete not fewer than 2 advanced nuclear reactor demonstration projects by not later than December 31, 2025; and

"(B) establish a program to demonstrate not fewer than 2, and not more than 5, additional operational advanced reactor designs by not later than December 31, 2035.

"(2) REQUIREMENTS.—In carrying out demonstration projects under paragraph (1), the Secretary shall—

"(A) include diversity in designs for the advanced nuclear reactors demonstrated under this section, including designs using various—

"(i) primary coolants;

"(ii) fuel types and compositions; and

"(iii) neutron spectra;

"(B) seek to ensure that—

"(i) the long-term cost of electricity or heat for each design to be demonstrated under this subsection is cost-competitive in the applicable market;

"(ii) the selected projects can meet the deadline established in paragraph (1) to demonstrate first-of-a-kind advanced nuclear reactor technologies, for which additional information shall be considered, including—

"(I) the technology readiness level of a proposed advanced nuclear reactor technology;

"(II) the technical abilities and qualifications of teams desiring to partner with the Department to demonstrate a proposed advanced nuclear reactor technology; and

"(III) the capacity to meet cost-share requirements of the Department;

"(C) ensure that each evaluation of candidate technologies for the demonstration projects is completed through an external review of proposed designs, which review shall—

"(i) be conducted by a panel that includes not fewer than 1 representative of each of—

"(I) an electric utility; and

"(II) an entity that uses high-temperature process heat for manufacturing or industrial processing, such as a petrochemical company, a manufacturer of metals, or a manufacturer of concrete; and

"(ii) include a review of cost-competitiveness and other value streams, together with the technology readiness level, of each design to be demonstrated under this subsection;

"(D) enter into cost-sharing agreements with partners in accordance with section 988 for the conduct of activities relating to the research, development, and demonstration of private-sector advanced nuclear reactor designs under the program;

"(E) work with private sector partners to identify potential sites, including Department-owned sites, for demonstrations, as appropriate; and

"(F) align specific activities carried out under demonstration projects carried out under this subsection with priorities identified through direct consultations between—

"(i) the Department;

"(ii) National Laboratories;

"(iii) institutions of higher education;

"(iv) traditional end-users (such as electric utilities);

"(v) potential end-users of new technologies (such as users of high-temperature process heat for manufacturing processing, including petrochemical companies, manufacturers of metals, or manufacturers of concrete); and

"(vi) developers of advanced nuclear reactor technology.

"(3) ADDITIONAL REQUIREMENTS.—In carrying out demonstration projects under paragraph (1), the Secretary shall—

"(A) identify candidate technologies that—

"(i) are not developed sufficiently for demonstration within the initial required timeframe described in paragraph (1)(A); but

"(ii) could be demonstrated within the timeframe described in paragraph (1)(B);

"(B) identify technical challenges to the candidate technologies identified in subparagraph (A);

"(C) support near-term research and development to address the highest-risk technical challenges to the successful demonstration of a selected advanced reactor technology, in accordance with—

"(i) subparagraph (B); and

"(ii) the research and development activities under section 958;

"(D) establish such technology advisory working groups as the Secretary determines to be appropriate to advise the Secretary regarding the technical challenges identified under subparagraph (B) and the scope of research and development programs to address the challenges, in accordance with subparagraph (C), to be comprised of—

"(i) private-sector advanced nuclear reactor technology developers;

"(ii) technical experts with respect to the relevant technologies at institutions of higher education; and

"(iii) technical experts at the National Laboratories.

"(d) GOALS.—

"(1) IN GENERAL.—The Secretary shall establish goals for research relating to advanced nuclear reactors facilitated by the Department that support the objectives of the program for demonstration projects established under subsection (c).

"(2) COORDINATION.—In developing the goals under paragraph (1), the Secretary shall coordinate, on an ongoing basis, with members of private industry to advance the demonstration of various designs of advanced nuclear reactors.

"(3) REQUIREMENTS.—In developing the goals under paragraph (1), the Secretary shall ensure that—

"(A) research activities facilitated by the Department to meet the goals developed under this subsection are focused on key areas of nuclear research and deployment ranging from basic science to full-design development, safety evaluation, and licensing;

"(B) research programs designed to meet the goals emphasize—

"(i) resolving materials challenges relating to extreme environments, including extremely high levels of—

"(I) radiation fluence;

"(II) temperature;

"(III) pressure; and

"(IV) corrosion; and

"(ii) qualification of advanced fuels;

"(C) activities are carried out that address near-term challenges in modeling and simulation to enable accelerated design and licensing;

"(D) related technologies, such as technologies to manage, reduce, or reuse nuclear waste, are developed;

"(E) nuclear research infrastructure is maintained or constructed, such as—

"(i) currently operational research reactors at the National Laboratories and institutions of higher education;

"(ii) hot cell research facilities;

"(iii) a versatile fast neutron source; and

"(iv) a molten salt testing facility;

"(F) basic knowledge of non-light water coolant physics and chemistry is improved;

"(G) advanced sensors and control systems are developed; and

"(H) advanced manufacturing and advanced construction techniques and materials are investigated to reduce the cost of advanced nuclear reactors.''.

(b) TABLE OF CONTENTS.—The table of contents of the Energy Policy Act of 2005 (Public Law 109–58; 119 Stat. 594) is amended—

(1) in the item relating to section 917, by striking ''Efficiency'';

(2) in the items relating to sections 957, 958, and 959, by inserting ''Sec.'' before ''9'' each place it appears; and

(3) by inserting after the item relating to section 959 the following:

''Sec. 959A. Advanced nuclear reactor research and development goals.''.

SEC. 5. NUCLEAR ENERGY STRATEGIC PLAN.

(a) IN GENERAL.—Subtitle E of title IX of the Energy Policy Act of 2005 (42 U.S.C. 16271 et seq.) (as amended by section 4(a)) is amended by adding at the end the following:

''SEC. 959B. NUCLEAR ENERGY STRATEGIC PLAN.

''(a) IN GENERAL.—Not later than 180 days after the date of enactment of this section, the Secretary shall submit to the Committee on Energy and Natural Resources of the Senate and the Committees on Energy and Commerce and Science, Space, and Technology of the House of Representatives a 10-year strategic plan for the

Office of Nuclear Energy of the Department, in accordance with this section.

"(b) REQUIREMENTS.—

"(1) COMPONENTS.—The strategic plan under this section shall designate—

"(A) programs that support the planned accomplishment of—

"(i) the goals established under section 959A; and

"(ii) the demonstration programs identified under subsection (c) of that section; and

"(B) programs that—

"(i) do not support the planned accomplishment of demonstration programs, or the goals, referred to in subparagraph (A); but

"(ii) are important to the mission of the Office of Nuclear Energy, as determined by the Secretary.

"(2) PROGRAM PLANNING.—In developing the strategic plan under this section, the Secretary shall specify expected timelines for, as applicable—

"(A) the accomplishment of relevant objectives under current programs of the Department; or

"(B) the commencement of new programs to accomplish those objectives.

"(c) UPDATES.—Not less frequently than once every 2 years, the Secretary shall submit to the Committee on Energy and Natural Resources of the Senate and the Committees on Energy and Commerce and Science, Space, and Technology of the House of Representatives an updated 10-year strategic plan in accordance with subsection (b), which shall identify, and provide a justification for, any major deviation from a previous strategic plan submitted under this section.".

(b) TABLE OF CONTENTS.—The table of contents of the Energy Policy Act of 2005 (Public Law 109–58; 119 Stat. 594) (as amended by section 4(b)(3)) is amended by inserting after the item relating to section 959A the following:

"Sec. 959B. Nuclear energy strategic plan.".

SEC. 6. VERSATILE, REACTOR-BASED FAST NEUTRON SOURCE.

Section 955(c)(1) of the Energy Policy Act of 2005 (42 U.S.C. 16275(c)(1)) is amended—

(1) in the paragraph heading, by striking "MISSION NEED" and inserting "AUTHORIZATION"; and

(2) in subparagraph (A), by striking "determine the mission need" and inserting "provide".

SEC. 7. ADVANCED NUCLEAR FUEL SECURITY PROGRAM.

(a) FINDINGS.—Congress finds that—

(1) the national security nuclear enterprise, which supports the nuclear weapons stockpile stewardship and naval reactors functions of the National Nuclear Security Administration, requires a domestic source of low- and high-enriched uranium in accordance with legal restrictions regarding foreign obligations relating to the beginning stage of the nuclear fuel cycle;

(2) many domestic advanced nuclear power industry participants require access to high-assay, low-enriched uranium fuel for—

(A) initial fuel testing;

(B) operation of demonstration reactors; and

(C) commercial operation of advanced nuclear reactors;

(3) as of the date of enactment of this Act, no domestic uranium enrichment or fuel fabrication capability exists for uranium fuel enriched to greater than 5 weight percent of the uranium-235 isotope;

(4) a healthy commercial nuclear fuel cycle capable of providing higher levels of enriched uranium would benefit—

(A) the relevant national security functions of the National Nuclear Security Administration; and

(B) the domestic advanced nuclear industry of the United States; and

(5) making limited quantities of high-assay, low-enriched uranium available from Department of Energy stockpiles of uranium would allow for initial fuel testing and demonstration of advanced nuclear reactor concepts, accelerating—

(A) the path to market of those concepts; and

(B) the development of—

(i) a market for advanced nuclear reactors; and

(ii) a resulting growing commercial nuclear fuel cycle capability.

(b) AMENDMENT.—

(1) IN GENERAL.—Subtitle E of title IX of the Energy Policy Act of 2005 (42 U.S.C. 16271 et seq.) (as amended by section 5(a)) is amended by adding at the end the following:

"SEC. 960. ADVANCED NUCLEAR FUEL SECURITY PROGRAM.

"(a) DEFINITIONS.—In this section:

"(1) HALEU TRANSPORTATION PACKAGE.—The term 'HALEU transportation package' means a transportation package that is suitable for transporting high-assay, low-enriched uranium.

"(2) HIGH-ASSAY, LOW-ENRICHED URANIUM.—The term 'high-assay, low-enriched uranium' means uranium with an assay greater than 5 weight percent, but less than 20 weight percent, of the uranium-235 isotope.

"(3) HIGH-ENRICHED URANIUM.—The term 'high-enriched uranium' means uranium with an assay of 20 weight percent or more of the uranium-235 isotope.

"(b) HIGH-ASSAY, LOW-ENRICHED URANIUM PROGRAM FOR ADVANCED REACTORS.—

"(1) ESTABLISHMENT.—Not later than 1 year after the date of enactment of this section, the Secretary shall establish a program to make available high-assay, low-enriched uranium, through contracts for sale, resale, transfer, or lease, for use in commercial or noncommercial advanced nuclear reactors.

"(2) NUCLEAR FUEL OWNERSHIP.—Each lease under this subsection shall include a provision establishing that the nuclear fuel that is the subject of the lease shall remain the property of the Department, including with respect to responsibility for the final disposition of all radioactive waste created by the irradiation, processing, or purification of any leased uranium.

"(3) QUANTITY.—In carrying out the program under this subsection, the Secretary shall make available—

"(A) by December 31, 2022, high-assay, low-enriched uranium containing not less than 2 metric tons of the uranium-235 isotope; and

"(B) by December 31, 2025, high-assay, low-enriched uranium containing not less than 10 metric tons of the uranium-235 isotope (as determined including the quantities of the uranium-235 isotope made available before December 31, 2022).

"(4) FACTORS FOR CONSIDERATION.—In carrying out the program under this subsection, the Secretary shall take into consideration options for providing the high-assay, low-enriched uranium under this subsection from a stockpile of uranium owned by the Department (including the National Nuclear Security Administration), including—

"(A) fuel that—

"(i) directly meets the needs of an end-user; but

"(ii) has been previously used or fabricated for another purpose;

"(B) fuel that can meet the needs of an end-user after removing radioactive or other contaminants that resulted from a previous use or fabrication of the fuel for research, development, demonstration, or deployment activities of the Department (including activities of the National Nuclear Security Administration); and

"(C) fuel from a high-enriched uranium stockpile, which can be blended with lower-assay uranium to become high-assay, low-enriched uranium to meet the needs of an end-user.

"(5) LIMITATION.—The Secretary shall not barter or otherwise sell or transfer uranium in any form in exchange for services relating to the final disposition of radioactive waste from uranium that is the subject of a lease under this subsection.

"(6) SUNSET.—The program under this subsection shall terminate on the earlier of—

"(A) January 1, 2035; and

"(B) the date on which uranium enriched up to, but not equal to, 20 weight percent can be obtained in the commercial market from domestic suppliers.

"(c) REPORT.—

"(1) IN GENERAL.—Not later than 180 days after the date of enactment of this section, the Secretary shall submit to the appropriate committees of Congress a report that describes actions proposed to be carried out by the Secretary—

"(A) under the program under subsection (b); or

"(B) otherwise to enable the commercial use of high-assay, low-enriched uranium.

"(2) COORDINATION AND STAKEHOLDER INPUT.—In developing the report under this subsection, the Secretary shall seek input from—

"(A) the Nuclear Regulatory Commission;

"(B) the National Laboratories;

"(C) institutions of higher education;

"(D) a diverse group of entities operating in the nuclear energy industry; and

"(E) a diverse group of technology developers.

"(3) COST AND SCHEDULE ESTIMATES.—The report under this subsection shall include estimated costs, budgets, and timeframes for enabling the use of high-assay, low-enriched uranium.

"(4) REQUIRED EVALUATIONS.—The report under this subsection shall evaluate—

"(A) the costs and actions required to establish and carry out the program under subsection (b), including with respect to—

"(i) proposed preliminary terms for the sale, resale, transfer, and leasing of high-assay, low-enriched uranium (including guidelines defining the roles and responsibilities between the Department and the purchaser, transfer recipient, or lessee); and

"(ii) the potential to coordinate with purchasers, transfer recipients, and lessees regarding—

"(I) fuel fabrication; and

"(II) fuel transport;

"(B) the potential sources and fuel forms available to provide uranium for the program under subsection (b);

"(C) options to coordinate the program under subsection (b) with the operation of the versatile, reactor-based fast neutron source under section 959A;

"(D) the ability of the domestic uranium market to provide materials for advanced nuclear reactor fuel; and

"(E) any associated legal, regulatory, and policy issues that should be addressed to enable—

"(i) the program under subsection (b); and

"(ii) the establishment of a domestic industry capable of providing high-assay, low-enriched uranium for commercial and noncommercial purposes, including with respect to the needs of—

"(I) the Department;

"(II) the Department of Defense; and

"(III) the National Nuclear Security Administration.

"(d) HALEU TRANSPORTATION PACKAGE RESEARCH PROGRAM.—

"(1) IN GENERAL.—As soon as practicable after the date of enactment of this section, the Secretary shall establish a research, development, and demonstration program under which the Secretary shall provide grants, on a competitive basis, to establish the capability to transport high-assay, low-enriched uranium.

"(2) REQUIREMENT.—The focus of the program under this subsection shall be to establish 1 or more HALEU transportation packages that can be certified by the Nuclear Regulatory Commission to transport high-assay, low-enriched uranium to the various facilities involved in producing or using nuclear fuel containing high-assay, low-enriched uranium, such as—

"(A) enrichment facilities;

"(B) fuel processing facilities;

"(C) fuel fabrication facilities; and

"(D) nuclear reactors.".

(2) TABLE OF CONTENTS.—The table of contents of the Energy Policy Act of 2005 (Public Law 109–58; 119 Stat. 594) (as amended by section 5(b)) is amended by inserting after the item relating to section 959B the following:

"Sec. 960. Advanced nuclear fuel security program.".

SEC. 8. UNIVERSITY NUCLEAR LEADERSHIP PROGRAM.

(a) FINDINGS.—Congress finds that—

(1) nuclear power plants—

(A) generate billions of dollars in national economic activity through procurements throughout the United States; and

(B) provide tens of thousands of people in the United States with high-paying jobs, contributing substantially to the local economies of the communities in which the plants operate;

(2) the world market for the growth of commercial nuclear power was estimated by the Department of Commerce to be valued at up to $740,000,000,000 during the period of calendar years 2018 through 2028;

(3) the participation and leadership of the United States in the market described in paragraph (2) will—

(A)(i) increase economic activity in the United States through robust nuclear exports, leading to the enhanced economic security of the United States; and

(ii) preserve and enhance the ability of the United States to positively influence international nuclear safety, security, and nonproliferation standards through commercial engagement with other nations; but

(B) require significant investment in United States-origin advanced nuclear technologies;

(4) in order to lead the world in the next generation of commercial nuclear power, the advanced nuclear industry in the United States should be positioned for accelerated growth, which requires public-private partnerships between industry entities and the Federal Government;

(5) success in achieving the goals described in this subsection will require a whole-government Federal approach that focuses on the shared needs and individual mission requirements of, at a minimum—

(A) the Department of Energy;

(B) the National Nuclear Security Administration; and

(C) the Nuclear Regulatory Commission;

(6) advanced reactors present new challenges and opportunities in reactor design, safeguards, and regulation;

(7) the challenges referred to in paragraph (6)—

(A) are directly relevant to the missions of—

(i) the Office of Nuclear Energy of the Department of Energy;

(ii) the National Nuclear Security Administration; and

(iii) the Nuclear Regulatory Commission; and

(B) require a highly skilled workforce in order to be met; and

(8) nuclear science and engineering programs at institutions of higher education in the United States—

(A) annually award degrees in nuclear engineering and related fields to more than 600 undergraduate students, and 500 graduate students, who are critical to maintaining United States leadership in the development of advanced nuclear systems;

(B) perform cutting-edge research and technology development activities that have made fundamental contributions to advancing United States nuclear technology; and

(C) support workforce development critical to maintaining United States leadership in nuclear detection, nonproliferation, nuclear medicine, advanced manufacturing, and other nonenergy areas.

(b) AMENDMENT.—Section 313 of the Energy and Water Development and Related Agencies Appropriations Act, 2009 (42 U.S.C. 16274a), is amended to read as follows:

"SEC. 313. UNIVERSITY NUCLEAR LEADERSHIP PROGRAM.

"(a) DEFINITIONS.—In this section:

"(1) ADVANCED NUCLEAR REACTOR.—The term 'advanced nuclear reactor' means—

"(A) a nuclear fission reactor, including a prototype plant (as defined in sections 50.2 and 52.1 of title 10, Code of Federal Regulations (or successor regulations)), with significant improvements compared to the most recent generation of fission reactors, including improvements such as—

"(i) additional inherent safety features;

"(ii) lower waste yields;

"(iii) improved fuel performance;

"(iv) increased tolerance to loss of fuel cooling;

"(v) enhanced reliability;

"(vi) increased proliferation resistance;

"(vii) increased thermal efficiency;

"(viii) reduced consumption of cooling water;

"(ix) the ability to integrate into electric applications and nonelectric applications;

"(x) modular sizes to allow for deployment that corresponds with the demand for electricity; or

"(xi) operational flexibility to respond to changes in demand for electricity and to complement integration with intermittent renewable energy; and

"(B) a fusion reactor.

"(2) INSTITUTION OF HIGHER EDUCATION.—The term 'institution of higher education' has the meaning given the term in section 101(a) of the Higher Education Act of 1965 (20 U.S.C. 1001(a)).

"(3) PROGRAM.—The term 'Program' means the University Nuclear Leadership Program established under subsection (b).

"(b) ESTABLISHMENT.—The Secretary of Energy, the Administrator of the National Nuclear Security Administration, and the Chairman of the Nuclear Regulatory Commission shall jointly establish a program, to be known as the 'University Nuclear Leadership Program'.

"(c) USE OF FUNDS.—

"(1) IN GENERAL.—Except as provided in paragraph (2), amounts made available to carry out the Program shall be used to provide financial assistance for scholarships, fellowships, and research and development projects at institutions of higher education in areas relevant to the programmatic mission of the applicable Federal agency providing the financial assistance with respect to research, development, demonstration, and deployment activities for technologies relevant to advanced nuclear reactors, including relevant fuel cycle technologies.

"(2) EXCEPTION.—Notwithstanding paragraph (1), amounts made available to carry out the Program may be used to provide financial assistance for a scholarship, fellowship, or multiyear research and development project that does not align directly with a programmatic mission of the applicable Federal agency providing the financial assistance, if the activity for which assistance is provided would facilitate the maintenance of the discipline of nuclear science or nuclear engineering.

"(d) AUTHORIZATION OF APPROPRIATIONS.—There are authorized to be appropriated such sums as are necessary to carry out the Program.".

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Questions for the Record Submitted to Dr. Mark Peters

Questions from Ranking Member Joe Manchin III

Question 1: Can you explain how materials science benefits the operations of our current nuclear fleet as well as helps the development of advanced reactors?

Advanced understanding of materials performance through materials science enables continued safe operations and improved performance of the current nuclear fleet, and will enable the benefits of advanced reactors.
For example, efforts to develop accident tolerant fuels uses principles of materials science to develop coatings for the existing zirconium-based cladding and develop entirely new iron-based cladding that will not be susceptible to oxidation events.
Furthermore, license extensions of commercial plants beyond 60 years will be dependent upon our ability to address issues of material aging and integrity, especially for reactors' pressure vessels and supporting concrete structures.
Advanced reactor designs look to take advantage of new fuel, cladding, and/or structural materials for improved performance and reduced costs. Qualifications of these new materials for nuclear applications demands rigorous characterization and prototype testing. This historically has been a costly and time-consuming process that discourages innovation and the timely deployment of new technologies. Because of this, modern science methods are needed to accelerate the materials discovery and qualification process.
Advanced post-irradiation examination instruments and capabilities, intelligent sensored irradiation experiments, and integrated modeling and simulation play a vital role in developing and qualifying advanced nuclear fuels and materials.
Advanced materials will enable market expansion for nuclear energy systems, making new applications practical. New materials that are tolerant of high temperatures and durable over long operating times will allow for integration of nuclear power systems into carbon-intense chemical process industries. Also, deployment of small, cartridge-core reactors will support military, emergency response and remote industrial application needs.
In summary, advances in material science can accelerate the discovery and qualification of new materials that will improve performance and reduce costs of current and advanced reactors.

Question 2: Can you describe why having a diverse set of technologies is critical to reducing carbon emissions, especially for meeting high heat industry and manufacturing needs?

It's projected that, over the next two decades, global population will increase 15 percent and energy consumption nearly 50 percent. Under the status quo, carbon emissions can be expected to rise accordingly. Nearly two-thirds of all CO2 across the globe related to energy use is emitted from four activities: electricity production (37 percent), heavy industry (11 percent), passenger vehicles (11 percent) and agriculture and related industries (8 percent).
Technology options are needed to support these different applications, which will see substantive change as we shift energy use from liquid fossil fuels to electricity in transportation, experience enormous growth

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in production of industrial products to meet growing demand, and see increased demand for agricultural chemicals and fertilizers driven by an expanding and increasingly affluent population.
As older industries are replaced and transformed, and new industries emerge, there will be a tremendous opportunity to create efficient, optimized, low-carbon energy systems using technologies that best match the applications.
A diverse set of technologies provides an integrated approach that satisfies the reliability, resilience and affordability needs of the energy system.
We have a generational opportunity to drive global markets with American innovation. Creating and preparing a diverse, competitive, low-carbon suite of technologies to meet these global realities should be approached with a sense of urgency.

Question 3: What additional innovations will help us lower the operating cost of the current fleet?

The greatest contributors to operating costs are in labor associated with maintaining legacy systems, manual activities to maintain, inspect and operate plant equipment, and provide a large security workforce at plants.
Replacing legacy analog instrumentation and control technologies with digital systems offers significant cost reductions through availability of parts, supply chain and a current technology base upon which innovation and cost reduction can be built.
Operating costs could be significantly reduced through: advanced sensors and instrumentation that offer improved monitoring of plant equipment and physical security; automation technologies and data analytics that assess equipment health and plant security status; and predictive tools that reduce unnecessary maintenance and operations.
Advanced risk-informed tools may also help lower operating costs through innovative approaches to safety management, operating life-cycle cost reduction, and risk-informed capital expenditures.
Finally, in partnership with industry, INL develops and tests concepts to improve accident tolerance and performance of light water reactor fuels. Developing materials better suited for very-high-temperature operations over extended periods of time will reduce costs and increase revenues for plant operators.

Question 4: Given the need for nuclear power in the context of climate change and the growing interest of investors, what additional programmatic or policy gaps do you see in any stage of the innovation pathway for advanced nuclear technologies?

We can enable advanced nuclear technologies, and the private-public partnerships needed to develop and deploy them, by addressing the following areas:

1) Calibrating the U.S. electricity markets to appropriately value nuclear energy for its clean, reliable and resilient attributes;
2) Setting measurable and achievable priorities on nuclear energy research and development, while increasing federal government R&D spending, to maintain pace with our international competitors;
3) Facilitating more private-public partnerships to accelerate time-to-technology commercialization, which we accomplish by granting more private industry access to national laboratory capabilities,

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facilities and expertise, creating cost-shared innovation centers, and ultimately demonstrating advanced reactor technologies;

4) Standardizing U.S. nuclear technology export policy to enable expansion of American exports;
5) Creating solutions to used fuel management, including storage and recycling options;
6) Continuing to reform the Nuclear Regulatory Commission (NRC) process and funding model to accommodate new nuclear technologies. A key aspect of this would be focusing the NRC not just on health and safety, but also efficiency. The current NRC mission statement reads: "The U.S. Nuclear Regulatory Commission licenses and regulates the Nation's civilian use of radioactive materials to protect public health and safety, promote the common defense and security, and protect the environment."

Emphasizing efficiency would provide much-needed balance. For example, the NRC mission statement could be changed to read: "The U.S. Nuclear Regulatory Commission licenses and regulates the Nation's civilian use of radioactive materials through the world's most efficient process while protecting public health and safety, promoting the common defense and security, and protecting the environment."

Question 5: How does workforce training need to be altered to better prepare the current and incoming workforce for advanced nuclear technology manufacturing and construction?

Workforce transitions have been a challenge for the nuclear industry for the past two decades. These have been intensified by recent retirements, resulting in the need to hire an estimated 4,000 nuclear power professionals each year for the next five years.
To fill that need, in a variety of specialties, and to attract the workforce that will be needed to construct, operate, and oversee advanced reactors, the following policy and investment approaches should be considered:

1) Assignment of a lead federal research-focused agency to steward professional workforce development;
2) Assistance (financial and advice) for community colleges who offer two-year nuclear technician training programs, including distance-learning options;
3) Development of a university-based nuclear training infrastructure program to specifically address research reactor modernization and simulator training for advanced nuclear systems;
4) Development of a high-visibility nuclear science and engineering intern and collaborative research program associated with the newly established National Reactor Innovation Center (NRIC);
5) Establishment of a national nuclear workforce council composed of industry, trade groups, labor, academia and national laboratory advisers to regularly assess needs of the advanced nuclear industry and make recommendations;
6) Establishment of an international technical exchange, intern and related programs to provide U.S. students and researchers experience with international markets and approaches, as global markets will be a growing outlet for American technologies;
7) Continued robust federal funding for university-based R&D programs.

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Question 6: What are the most pressing workforce needs in the advanced nuclear sector and has collaboration in the advanced nuclear sector started between the unions, national labs, and industry on meeting the workforce demands of the future?

In anticipation of advanced nuclear energy systems deployment, we identify three pressing workforce needs:

1) Consistent availability of engineering and science professionals trained in nuclear engineering and nuclear physics, chemistry, radiochemistry, health physics, electrical engineering and advanced modeling and simulation, particularly with advanced degrees. Of particular concern is the ability to recruit top engineering and science students to nuclear-related degree programs given competition from other fields and the ongoing transitions among university faculty in nuclear-related degree programs.
2) The availability and stability of nuclear energy-specific training and education tools, particularly research reactors and simulation-based training tools;
3) The availability of nuclear-trained technicians and plant operators, particularly at the associate/bachelor's degree levels.

Collaborative efforts between unions, national laboratories, industry, academia and others have been underway for some time. In fact, skilled professionals are being attracted in part because of media campaigns that identify training programs, and by making an effort to reach out to highly skilled nuclear-trained professionals transitioning from military service.

Of key strategic importance for the advanced nuclear energy industry was recognition of the challenge posed by declining university enrollment in nuclear energy programs. More than 15 years ago, the U.S. Department of Energy Office of Nuclear Energy offered more funding opportunities for university participation, sparking additional collaborations between the national laboratories, private sector and universities. That resulted in substantial growth in numbers and high-quality student pipelines.

These approaches continue, and the industry collaboration portion has been enhanced. These efforts are vital to the recruiting and training of the nuclear energy workforce of today and tomorrow, especially as nuclear energy competes with growing technology and manufacturing industries for the best and brightest engineering and science talent.

Questions from Senator Mike Lee

Questions: Can you describe the NRC's current ability to license advanced nuclear reactors? How can that process be improved? It is our understanding that NuScale's advanced nuclear reactor design certification application has advanced the furthest through the NRC's review and licensing process. Can we learn anything from NuScale's experience?

Because much of the existing regulatory framework is structured to address the large light water reactors of the current operating fleet, the NRC process for advanced, nonwater reactors is inefficient and resource intensive.

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The commission established an Implementation Action Plan in 2017 to address and resolve inefficiencies and regulatory uncertainties regarding non-LWR technologies, and that includes a series of near term (within five years) and longer-term actions to address the most significant challenges.

Working with industry stakeholders, the NRC is making considerable progress in resolving long-standing policy issues, updating license technical requirements, developing an updated set of confirmatory analytical tools, and expanding NRC staff training on advanced technologies as they prepare to review advanced reactor license applications.

As stated earlier in a response to a question from Sen. Manchin, the NRC process could be improved by focusing not just on health and safety, but also on efficiency.

Two excellent examples are the Food and Drug Administration (FDA) and Federal Aviation Administration (FAA). The FDA's mission is to protect public health by assuring the "safety, efficacy and security" of products under its purview. The FAA's mission is to provide the "safest, most efficient aerospace system in the world."

The NuScale Power effort to license its advanced LWR technology is identifying opportunities for continued process improvements that can be applied by the NRC and industry to the licensing efforts of non-LWR technologies moving forward.

For instance, the NRC staff developed and piloted a more risk-informed approach to a specific area (instrumentation and control) of the NuScale design, resulting in a more streamlined and efficient technical review of that portion of the license application.

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Questions from Ranking Member Joe Manchin III

Question 1: Can you explain how materials science benefits the operations of our current nuclear fleet as well as helps the development of advanced reactors?

Materials science is foundational to many of today's challenges and advancements in energy technologies generally and in nuclear technologies in particular. Advances in materials science can enable:
- Higher temperature operation to increase efficiency and lower costs or to provide heat for industrial processes, energy storage, or zero-carbon liquid fuel or hydrogen production.
- Greater safety margin and accident-tolerant fuels that are more resilient, provide longer coping time during a loss of cooling event, and allow more flexible operation
- Longer refueling cycles for operating and future plants which improves economics, increases availability, and reduces access to nuclear materials
- Higher performance spent fuel storage, immobilization, and/or disposal
- Radiation-tolerant materials that enable longer fuel cycles in a fast neutron environment, the consumption of long-lived waste products within the reactor and a consequent reduction in spent nuclear fuels and nuclear waste.
- Better understanding of long-term behavior of materials that is particularly important to considering second license renewal for currently operating plants.
- Improved prediction of material behavior through modeling and simulation.

Question 2: Can you describe why having a diverse set of technologies is critical to reducing carbon emissions, especially for meeting high heat industry and manufacturing needs?

Studies consistently show that a diverse set of technologies increases the feasibility and decreases the cost of reducing carbon emissions.

To mitigate climate change, 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, into non-electric energy, where nuclear energy has strong potential to contribute.

We can build a stronger and more resilient electric power system when there are a diversity of sources playing various roles. Fundamentally, the system operator needs to balance supply and demand instantaneously, and perpetually – that is a tall order, especially when the vagaries of our demand curve depend on weather, vacation, events, time of day, season, etc. It takes several different types of generation to piece that puzzle together from one minute to the next. There has been ample analysis of this challenge, summarized below.

Non-electric energy decarbonization

When we look to decarbonize non-electric energy, we find that characterization of the path forward has been more segmented and incomplete. It is clear, though, that the challenge makes electricity decarbonization look like a proverbial "walk in the park." While the electric power load curve is highly variable, the demand is always for electrons at 60 Hz. Elsewhere there is a need for heat of all different temperatures, for electricity at times, for liquid fuels, for hydrogen, and the picture is much more complex and localized. At the same time, the performance requirements don't become more forgiving. Aircraft need particular fuel characteristics to stay airborne, and industrial processes need heat delivered reliably and precisely to suit their needs.

Several promising approaches are emerging, and nuclear energy could play an important role in any or all of them. Increased electrification will play a role in transportation as well as perhaps heating and some industrial applications. Nuclear energy has a straightforward role in this aspect. Other pathways for non-electric sector decarbonization include the following approaches:

- Hydrogen, either in its pure form or in a "carrier" such as ammonia (NH_3) has the potential to play a major role in decarbonizing land, sea, and air transport. It is highly versatile and could also be used as an energy storage medium, for thermal needs, and for bulk or peaking electric power. It is used as a feedstock in many industrial processes. Production of hydrogen from nuclear energy has been studied in the past, but interest has recently ramped up. Idaho National Lab and several other research groups are pursuing the topic, Japan is expanding its research into a hydrogen economy, and several currently operating U.S. nuclear power plants are preparing for hydrogen production demonstration projects. The National Energy Technology Laboratory has a number of programs pursuing new hydrogen-production technologies and improvement of existing technologies.
- Heat, in the form of steam at various temperatures, is used to drive many industrial processes as well as to provide district heating. Nuclear energy has been paired with industrial processes and district heating in the past, and it is presently being used internationally for desalination, paper and cardboard plants, and district heating. Some industrial heat demands are not easily or efficiently electrified, but currently rely on carbon-intensive fuels. At the same time, these operations typically run at high capacity factor and rely on high-availability of their energy supply. This makes nuclear energy a natural option.
- Direct carbon removal from the environment either from air or water is being incorporated into many decarbonization scenarios. The technology to perform the removal is being commercialized and relies on abundant low-carbon energy. Nuclear energy is one of the promising bulk energy options available for this process.

<u>Electricity decarbonization</u>

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.

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- 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.[1]

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."[2] 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.

[1] Jenkins, Luke & Thernstrom (2018), "Getting to zero: insights from recent literature on the electricity decarbonization challenge," *Joule 2*, 2487-2510, December 19, 2018.
[2] 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

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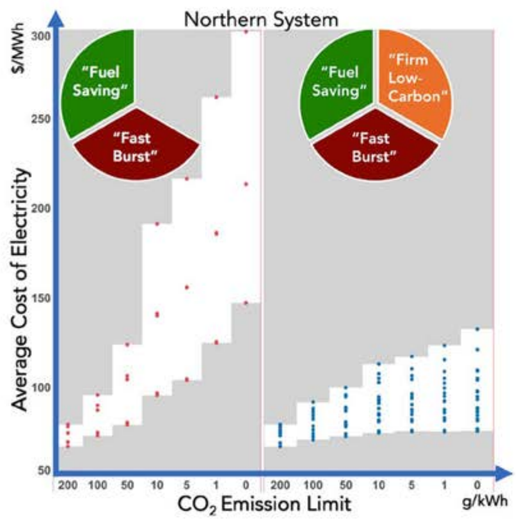

Figure 1: Average Cost of Electricity under Various Technology Assumptions and CO_2 Emission Limits for the Northern System (a) with a decarbonization policy that ex-ante excludes firm low-carbon resources on the left and (b) with a decarbonization policy that includes firm low-carbon resources on the 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.[3] 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.

Question 3: What additional innovations will help us lower the operating cost of the current fleet?

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

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Lower operating costs can come from plant modernization and improved workforce efficiency. Additionally, current plants can enhance their competitiveness by exploring more diverse products (e.g. heat, hydrogen, energy storage) and by offering more flexible operation (making electric power when it is most needed and thus most valuable).

Plant modernization innovation efforts include:
- Control room modernization and transition to digital instrumentation (analog parts are very difficult to obtain)
- Enhanced online monitoring to improve knowledge of the plant condition and focus periodic human inspections where they are most effective
- Materials research to understand and control degradation
- Risk-informed in-depth analysis of plant operating margins to improve plant efficiency

Innovations to improve workforce efficiency include:
- Plant worker optimization modeling
- Investigation into physical security approaches that are less labor-intensive.

Innovations to improve competitiveness by improving the products offered include:
- Integrated energy systems research and modeling
- Increasing capacity for ramping power in the current fleet (this is being piloted in some plants)
- Developing hydrogen production module designs for existing nuclear power plants
- Developing designs for deploying energy storage systems at existing nuclear power plants.

This list is not exhaustive.

Question 4: Given the need for nuclear power in the context of climate change and the growing interest of investors, what additional programmatic or policy gaps do you see in any stage of the innovation pathway for advanced nuclear technologies?

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 (see the recent NIA report for more details: https://www.nuclearinnovationalliance.org/spacexfornuclear)
3. An executive order putting in place a more aggressive federal Clean Energy Standard that includes nuclear;

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4. State or federal clean energy standards and/or market modifications that prioritize characteristics that are necessary to reliable clean power grid function.
5. 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. DFC (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;
6. 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
7. 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.

Question from Senator Mike Lee

Question: How does mining regulation impact access to domestic sources of uranium and other minerals that may be necessary for the success of advanced nuclear in the future?

Mining regulation is not currently an area of NIA expertise, but I'd encourage you to reach out to the Nuclear Energy Institute and the Uranium Producers of America; those organizations would be able to offer more detailed and insightful comments on this topic.

Uranium fuel for existing reactors is widely available on the commercial market, but a key challenge for many advanced reactors will be securing a supply of high-assay, low-enriched uranium for early advanced reactors, before a commercial supply is established. High-assay, low-enriched uranium is enriched between 5% and 20% uranium-235 by weight, and currently there is not a commercial supply of this material in the United States. Congress and DOE have taken steps to address this, but continued progress and vigilance will be needed to ensure that a supply is available when it is needed.

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Questions for the Record Submitted to Maria Korsnick

Nuclear Energy Institute Responses to Questions for the Record

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Questions from Ranking Member Joe Manchin III

Question 1: How does workforce training need to be altered to better prepare the current and incoming workforce for advanced nuclear technology manufacturing and construction?

The Nuclear Energy Institute anticipates the need to educate and train a well-qualified workforce for designing and fabricating Advanced Manufacturing Methods (AMM) components for the nuclear industry. To date, pursuit of AMM in the nuclear industry has largely been a technology development activity. Experts from industry, the National Laboratories, and academia have made significant progress in building on AMM from other industries as well as developing and adapting methods for application in the nuclear industry. However, if AMM use is to become commonplace in the nuclear industry, developing a skilled workforce to both design and produce AMM components will be a major consideration. Given the nature of some AMM techniques, engineering skills may need to be augmented with advanced computer training.

We will continue working closely with the construction union joint apprenticeship programs on developing unique construction techniques for advanced reactors.

Question 2: What are the most pressing workforce needs in the advanced nuclear sector and has collaboration in the advanced nuclear sector started between the unions, national labs, and industry on meeting the workforce demands of the future?

Industry, unions, the national labs, and academia have a demonstrated ongoing history of collaborating effectively on workforce-related issues and nuclear training and education programs (e.g., Nuclear Mechanic Apprenticeship Process, Nuclear Uniform Curriculum Program, Center for Advanced Energy Studies). Although specialized curricula may become necessary in the future to address advanced technologies, the immediate priority is to ensure consistent and viable talent pipelines to the industry, particularly given retirement attrition. These include:

- Trade schools
- Apprenticeship programs
- Two-year colleges that develop skilled technical professionals
- Four-year universities that produce professional engineers and allied professionals

A strong foundation for these programs is being built through *Navigating Nuclear: Energizing Our World*, a K-12 program that teaches the fundamentals of nuclear energy.

Question from Senator Mike Lee

Question: How does mining regulation impact access to domestic sources of uranium and other minerals that may be necessary for the success of advanced nuclear in the future?

Although we do not see mining regulation as a challenge for the success of deploying advanced nuclear reactors in the future, there are opportunities to better streamline permitting and risk-inform the regulatory framework for the licensing and operations of U.S. uranium mines. Historically, the NEPA review process has been one factor that has led to lengthy licensing times. Additionally, there is duplicative regulation between the EPA programs, which are administered by the states, and the NRC program, which in some cases is overseen by NRC and the Agreement States.

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Questions for the Record from the April 30, 2019 Senate Committee on Energy & Natural Resources Hearing

United Association of Union Plumbers and Pipefitters (UA) of the United States and Canada

General President Mark McManus

Questions from Ranking Member Joe Manchin III

Question 1: How does workforce training need to be altered to better prepare the current and incoming workforce for advanced nuclear technology manufacturing and construction?

In order for any organization to better prepare its workforce for future industry needs they must embrace and train their members in the very latest technologies. This has been a cornerstone on how the United Association of Union Plumbers and Pipefitters (UA) has trained its membership since its founding in 1889. We are proud to say that in 1936 the United Association became the first nationally registered joint apprenticeship program in the United States. A well-trained workforce and effective use of technology are viewed as having a major influence on the successful completion of projects. The productivity and safe practices of that workforce are also seen as strong influencers. We know that the path to a safe, productive jobsite begins at the door of an accomplished, relevant training program. As an organization, the UA constantly monitors and incorporates the technological advances and various methods of training that are being utilized in the construction and manufacturing industry.

More than ever an increasing number of projects are being driven by the latest technologies and equipment, which has resulted in increased productivity through a greater efficiency of planning, communication and execution. The construction workforce must be at the forefront of this innovative technology. Due to the competitive nature of construction, owners and contractors are constantly seeking additional ways to lower costs and to run their operations more efficiently. One of the ways they are doing this is by introducing timesaving technologies and equipment that will aid workers in the field. Other examples of recent innovations include: real-time apps, software programs that allow the user to solve up-to-the-minute problems, mobile devices that permit the user to assess project information from the field and virtual-reality simulations that can help predict challenges ahead of time.

Workers need to be trained in 3-D environments and mobile technologies, such as BIM (Building Information Modeling), CAD (Computer Assisted Design), robotic layout and laser scanning technologies. Expanding the use of virtual and augmented training programs and equipment is a must for any organization looking to prepare their members for future construction projects. The use of on-line resources should also be included in trades training programs by providing members a constant access to training information and materials. In addition, there have been improvements in welding technology that significantly improve the productivity and quality of welded construction activities. Training in the application and use of these new welding technologies to meet industry needs is critical when talking about future nuclear construction projects. Embracing these new environments and technologies will promote the level of worker skills, which will support safety, quality, and economical construction activities.

All of the aforementioned requires a considerable amount of time and money to effectively implement. For example the United Association spends over $250,000,000 a year in training its members. The UA has made it its mission to stay informed as new technologies and equipment enter the marketplace. We're reaching out and developing new partnerships with major companies and manufacturers that are developing state-of-the-art software and equipment. Through these partnerships, we've been able to provide some unique training opportunities. There is no doubt that UA-trained piping professionals will be the most qualified to embrace the new technologies entering the field -- we are truly the piping experts. The UA's Education and Training Department has been very forward thinking on this issue, and as the industry continues to take a hard look at new technology, the UA is prepared to train for and embrace the technology that makes it into the field. Only this this kind of resolute commitment to educating and training workers will ensure we will meet the current and future needs of the nuclear industry.

Question 2: What are the most pressing workforce needs in the advanced nuclear sector and has collaboration in the advanced nuclear sector started between the unions, national labs, and industry on meeting the workforce demands of the future?

One of the biggest challenges facing large industrial projects is skilled manpower. Getting the right workers with the right qualifications and experience is the key to any successful project. Since the mid-1980s, the United Association (UA) has worked closely with nuclear utilities to ensure that our members are trained to the specific needs of our nuclear plants. One of the ways in which we have accomplished this is through the Nuclear Mechanic Apprenticeship Process (NMAP), which was developed by a tripartite committee of international building trades unions, contractors and nuclear utilities. The NMAP is a formal method to provide evidence that the entry level knowledge and skills training requirements required by industry have been met by contracted craft labor union personnel on an individual basis. The process utilizes the well-structured and effective craft labor union apprenticeship programs and provides a sound basis for stating that an individual who successfully completes the unions' apprenticeship program possesses the basic knowledge and skills described by the Institute of Nuclear Power Operations (INPO) to perform work independently in a nuclear power facility.

To further meet industry's need for a better way to assess worker proficiency, the UA collaborated with the Electrical Power Research Institute (EPRI) -- an independent research organization recognized as the national leader when it comes to ensuring electric power is safe, reliable, affordable and environmentally friendly -- to define and develop standardized testing evaluations. The standardized testing evaluation process is a programmatic approach to testing the knowledge and skills required to perform specific tasks, and then documenting an individual's performance to allow for portable qualifications. The UA currently maintains three certification programs that operate under the EPRI standardized testing and evaluation model:

- The Industrial Rigging Certification Program: Designed to ensure that UA members are able to take on any rigging task they may encounter when rigging for lifts of materials or equipment.
- The Valve Technician Certification Program: Provides confidence to both contractors and end-users that our members are qualified to inspect and repair the different types of valves in use at industrial facilities.
- The Instrumentation Technician Certification Program: Ensures individuals are qualified in the calibration, maintenance and repair of the numerous types of instrumentation devices found in industrial systems.

The Institute of Nuclear Power Operations (INPO), which sets performance objectives, criteria, and guidelines industry-wide for nuclear power plant operations, were concerned that there was no verification that organizations were conducting the practical performance examinations correctly. To address these concerns EPRI developed the Administration Protocol for Portable Practicals (AP3) as a means of providing oversight of organizations (e.g. utilities, contractors and unions) that conduct the hands-on practical performance exams, wherein they send out an audit team to check-up on organizations that use the EPRI evaluation qualification programs. It is of significant note that the United Association was the very first organization to have satisfactorily completed the audit process and be qualified to perform standardized testing evaluations of personnel. These UA programs streamline qualification procedures, ensure quality work, and save time and money for contractors and end-users and effectively meet industry needs for a skilled, dependable, and readily available workforce.

Another critical issue for the nuclear sector is the need for skilled and qualified welders. The UA addressed this issue beginning in 1993 when it instituted the UA Welder Certification Program. The UA had the foresight to recognize early on the piping industry participant's expressed need for the standardized qualification of pipe welders. In many areas of the industry, the current and past practice of industry participants has resulted in incomplete welder qualifications. In order to ensure a standardized and auditable process the testing and qualification of welders must be conducted in accordance with a national standard, the UA chose the American Society of Mechanical Engineers (ASME) Section IX Boiler & Pressure Vessel Code for the Qualification of Welders. There are over 61,000 UA welders currently qualified under our program. The program promotes third party oversight and establishes a uniformity that will protect the interests and responsibilities of the manufacturer/contractor and the owner/user. Benefits such as weld quality and consistency, welder competence, plant safety and work force flexibility and availability as well as the economic benefits can be realized through acceptance of this program.

In response to the question over collaboration between unions and industry participants you could find no better example than the UA's Tripartite Initiative. For the United Association, its contractor partners and construction project owners, working together is much more than just a concept; it's a reality that has generated great success over the past several years. Together, all three parties are walking the walk of true collaboration and partnership. The tripartite idea was born from awareness that all the stakeholders on a construction job share the same goal: to have a project completed on time, on budget and, most of all, safely. The concept of the UA Tripartite Initiative is to bring together contractors and project owners along with local union officers, training coordinators and industrial specialists to explore what works, what changes are needed and how they could move forward together to make for a successful project.

Since its start more than a decade earlier our process of tripartite collaboration continues to focus on success stories and strategies that can be applied to virtually any construction project. Over the years, the process has explored the impact of new technologies, the challenges brought by manpower shortages and the need for different approaches to training, such as site-specific training. One of the most powerful pieces of evidence that the tripartite approach is working happens each year at the UA National Tripartite Conference which has grown in size annually. In 2019, several hundred participants attended the conference, including many large contractors and project owners. This is powerful proof this process works and brings valuable ideas and tactics that labor, management and owners can apply on their own jobsites. Through panel discussions and wide-ranging question-and-answer sessions, the conference continues to break new ground and creates a valuable learning experience for everyone.

The UA has an excellent relationship with our contractors and end-users, and our goal is to continue to provide our industry partners with a skilled workforce that represents our 'Built on Excellence' campaign. This campaign includes three important factors that are the result of any successful project, a strong Standard for Safety, a consistent Standard for Excellence and, our most-recent addition, our Standard for Productivity. These standards represent the core values of the tripartite partnership. More than simply words on paper, these values reflect the standards that are now part of the wider culture on every United Association jobsite in the U.S. and Canada. Journeymen and women, as well as apprentices, all commit formally to these standards, which enable contractors and project owners to rely on what amounts to a pledge to provide the highest quality and productivity on every job every day -- and to do it safely.

There is no finer example of the tripartite approach than the Cove Point LNG expansion project located in Calvert County, Maryland. The construction of Cove Point began in early fall of 2014. The Cove Point terminal has a storage capacity of 14.6 billion cubic feet (BCF) and a daily send-out capacity of 1.8 BCF. The terminal connects, via its own pipeline, to the major Mid-Atlantic gas transmission systems of the Transcontinental Gas Pipeline, Columbia Gas Transmission and Dominion Transmission pipelines. The new facility is being designed to process, on average, 750 million standard cubic feet per day of inlet feed gas. Cove Point has become the poster child for a successful large, sophisticated project. It is up and running and is currently exporting liquid natural gas. The partnership that was forged between the UA and its local unions, Kiewit Power Constructors, and Dominion Energy was key to its success.

At Cove Point monthly tripartite meetings were held, always with representatives of the plant owner, major contractors and union labor in attendance. The premise of these meetings was to provide a forum to discuss the project status and address any issues in a collaborative manner. These meetings included superintendents, stewards, construction managers. The rest of industry was watching Cove Point to see how effective our innovative approach would prove to be. In the end, it showed that the UA and our collaborative approach was a strategy that worked and should be replicated. We firmly believe it has set the standard for what is expected by the union crafts, contractor management, and owners. For complex projects such as Cove Point to work, there has to be the highest level of commitment, trust, and communication. Everyone has to be onboard. Union members understood they were not just completing their individual jobs, they were building a world-class liquid natural gas plant, and they did just that.

Going forward, it is clear that success is only achieved when the workforce, contractors, and the owners work together toward the end goal—the successful completion of projects.

U.S. Senate Committee on Energy and Natural Resources
April 30, 2019 Hearing: *Pathways to Reestablish U.S. Global Leadership in Nuclear Energy and to Receive Testimony on S. 903, the Nuclear Energy Leadership Act*
Questions for the Record Submitted to the Honorable Jeffrey S. Merrifield

Questions from Senator Mike Lee

Question 1: Can you describe the NRC's current ability to license advanced nuclear reactors? How can that process be improved? It is our understanding that NuScale's advanced nuclear reactor design certification application has advanced the furthest through the NRC's review and licensing process. Can we learn anything from NuScale's experience?

Merrifield Answers:

Can you describe the NRC's current ability to license advanced nuclear reactors?

The NRC is capable of licensing advanced reactors under either its Part 50 (separate construction and operating licenses) or Part 52 (combined construction and operating license) programs. In my view, the issues that the NRC will need to deal with to be successful in this program is having sufficient technical capabilities to review the molten salt, high temperature gas and fast reactor designs they are likely to see as applicants in the next few years. While the NRC is working to bolster its technical capabilities, this is clearly an area of concern and one that Congress should continue to monitor. I also believe that there needs to be additional focus placed on the Agency's readiness to manage the oversight of the non-reactor elements of these designs. In particular, it will be important for the Agency to appropriately manage their technical staff in the areas of security and safeguards, fuel cycle (new and used fuel), emergency planning and environmental permitting. I remain concerned that the staff in these disciplines are not fully focused on the rapid development of these advanced reactor designs and in the absence of being fully prepared, could be overly conservative in their reviews in a manner that could hinder the safe and timely deployment of these designs. As a general matter, these focus areas have a history of over conservatism in their approaches to licensing and these tendencies if not appropriately managed could have an adverse effect on the ability to deploy advanced nuclear designs.

How can that process be improved?

First, I believe that Congress needs to continue to provide sufficient funding, off the fee base, to allow the Agency to prepare itself for these reviews, including monies targeted toward the fuel cycle activities involving advanced reactors. Second, I think Congress should closely monitor the Agency's preparations in the areas of emergency preparedness, environmental permitting, safety and safeguards. Given the significantly safer operation of these future advanced reactors, over conservatism by the NRC could adversely impact the ability to deploy these designs in a timely, safe and appropriate fashion.

Further, I think it is important for the NRC to set a firm and efficient schedule for these reviews and lay out a timetable to which they can be held accountable by Congress to meet (recognizing that the applicant must also timely provide information). As part of this effort, the NRC must continue to make improvements in its technical review program, including the process for managing requests for additional information (RAIs) from the applicant. Managing the RAI process became badly broken after I left the Agency in 2007 with numerous duplicative or non-risk focused questions being submitted by NRC staff. While the Agency has made progress in this area, the Commission and senior NRC managers must continue to be held accountable for managing this process. While it is the duty of the Agency to regulate the deployment and use of nuclear reactors and materials in a manner that is protective of people and the environment, it must do so in a manner that is not unnecessarily burdensome in either cost or time.

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As I was not involved in the detailed preparation or review of the NuScale application or licensing activities, and thus, I am limited in my knowledge of this subject. That said, it is obvious that NuScale broke new ground in considering different approaches to control room staffing, emergency planning and other key policy issues associated with its design. This took significant time and effort, and NuScale should be commended for having taken the lead on suggesting these policy changes that have been or may be adopted by the Commission. Many advanced reactor developers will be able to take advantage of these policy changes which allow for a more tailored approach to licensing reviews given the significantly smaller risk posed by these designs. As stated above, I believe the RAI process remains an area of concern, albeit it is improving, and I believe NuScale did suffer needless time and expense as a result of the NRC review activities.

Question 2: *In your testimony, you discuss nuclear export opportunities. Where is our domestic industry relative to Russian and Chinese efforts? How does the regulatory environment in the U.S. compare to that of those competitors?*

China and Russia represent two formidable international competitors in the international market for nuclear reactors. While their designs are safe, they do not appear to have the same level of technological innovation as more modern American based designs that rely on passive safety features. The more difficult matter is the issue of cost. Chinese and Russian reactors are priced far more aggressively, they receive larger levels of financing support as state owned enterprises, and their governments place significantly greater levels of non-nuclear support to "sweeten the package".

While Secretary Perry and the Trump Administration are to be commended for increasing the amount of support behind U.S. nuclear exports, there will need to be greater efforts by the Departments of State and Commerce, the Ex-Im Bank, and the newly created Development Finance Corporation to provide the support and resources to assist U.S. nuclear technologies to effectively compete in the international market. In order for the U.S. nuclear industry to be successful, it will also necessitate involvement of non-nuclear deliverables, including infrastructure investment and potentially military sales to match the offerings provided by our international competitors.

When it comes to the quality of its technology, particularly advanced reactors, the U.S. takes a back seat to no other country, but in order to win, these developers and suppliers need a coordinated, whole of government approach, to win our fair share of these opportunities. As these reactor sales help establish the foundation for 60-80 years of relationships between the host country and the country of the nuclear supplier, the strategic value of having strong U.S. involvement is enormously consequential for national security reasons – a fact that was well understood by President Dwight David Eisenhower when he established the Atoms for Peace program in the 1950's.