

THE LATEST DEVELOPMENTS IN THE
NUCLEAR ENERGY SECTOR, WITH A
FOCUS ON WAYS TO MAINTAIN AND
EXPAND THE USE OF NUCLEAR ENERGY
IN THE UNITED STATES AND ABROAD

HEARING
BEFORE THE
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

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THURSDAY, MARCH 25, 2021

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

The Committee met, pursuant to notice, at 9:45 a.m. in Room SD-366, Dirksen Senate Office Building, Hon. Joe Manchin III, Chairman of the Committee, presiding.

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

The CHAIRMAN. The Committee will come to order.

First of all, thanks to all of you. I will do it more formally when I do this, but I want to thank you all for being here. It is going to be a very important meeting that we have today.

I am pleased to focus our conversation today on nuclear technology and how we can maintain and expand the use of nuclear energy both domestically and abroad. I want to thank our witnesses, who will provide us with a vision of our nuclear energy future. A lot happened in the last year on the nuclear front. First and foremost, we passed the Energy Act with the Advanced Reactor Demonstration Program (ARDP), which was spearheaded by Senator Murkowski. We also were successful in lifting the Development Finance Corporation's ban on civil nuclear financing, allowing the U.S. to offer more competitive deals to the international community. Two of our witnesses, TerraPower and X-energy were selected as winners of the Department of Energy Advanced Reactor Demonstration Program—congratulations. And \$75 million was appropriated to initiate a uranium reserve while we also authorized the Russian suspension agreement to prevent manipulation of our energy markets.

With those accomplishments behind us, we still have a lot of work ahead of us. The public remains cautious about nuclear energy. Congress must pass legislation that allows states to have buy-in when it comes to the nuclear repository site selection and construction and we must ensure that the National Nuclear Security Administration has the proper resources to operate their non-proliferation and safeguards program in coordination with the

International Atomic Energy Agency. I look forward to working with members of this Committee to accomplish these objectives.

But today, I want to focus on our efforts to build advanced reactors. The Department of Energy and our national laboratories play a central role in leading this effort in concert with private advanced nuclear energy companies. This public-private relationship is incredibly important, especially in delivering financing to commercialize these reactors. Already, private investments have surpassed \$1.3 billion. This is largely because of their enormous market potential for electricity, process heat for manufacturing, electrolysis for hydrogen production, and desalinization.

We include important provisions with the Energy Act, directing the continued research on how to develop hybrid and integrated energy systems to operate seamlessly together. Idaho National Lab (INL), the National Renewable Energy Lab (NREL), and the National Energy Technology Laboratory (NETL) in Morgantown, West Virginia, are leaders in this effort. Nuclear power provides about ten percent of the world's electricity and prevents approximately two gigatons of carbon from reaching our atmosphere every year. But about 789 million people around the world still live without any electricity. Nuclear energy can be part of delivering that electricity to lift people out of poverty and provide the opportunities that many have become accustomed to. The Tennessee Valley Authority (TVA) was created to do that very thing during the Great Depression. This is a model that can inform our efforts, both domestically and abroad. Russia and China have made a strategic effort to supplant our nuclear leadership over recent years and we must push back. With the necessary policy and funding, we can maintain our nuclear supply chain, create high-paying manufacturing jobs, and reassert U.S. leaderships.

We also need to discuss the role of our existing fleet, where we are seeing more closures. This year alone, five reactors at three locations with 5.1-gigawatt capacity are slated to close. The International Energy Agency (IEA) found that across the advanced economies, if countries continue to allow nuclear reactors to be prematurely shut down, it will be \$80 billion a year more costly to meet emission goals—that is \$80 billion more each year. Lifetime extensions are cheaper than new builds and are generally cost-competitive with other generation technologies. We cannot afford to let this carbon-free energy resource fade out.

So with that I will turn it over to the Ranking Member, Senator Barrasso, for his opening statement.

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

Senator BARRASSO. Well, thank you very much, Mr. Chairman. Thanks for holding this very important hearing today.

Now more than ever, Washington must advance policies to preserve and expand the use of nuclear energy. Nuclear technology is fundamental to meeting our energy, environmental, and national security goals. Nuclear power is our nation's largest source of carbon-free energy. In turn, it is critical to reliable, resilient, and affordable electric service. During last month's cold snap, nuclear power plants, by one key metric, outperformed all other energy

sources. For the last 75 years, America's nuclear energy industry has been the world's leader in safety, as well as performance. We need to ensure our leadership endures.

As we speak, America's adversaries, Russia and China, seek to undermine our nuclear industry. Russia and its satellites have intentionally dumped uranium into our market. They undercut American uranium producers and processors. They drive our companies out of business. America's uranium production is so low, it is now at a level not seen since the 1940s. We are on the brink of finding ourselves completely reliant on foreign uranium to power our nuclear power plants. This is unacceptable. The Biden Administration must take decisive action to prevent this from happening. Last year, Congress appropriated \$75 million to establish a national uranium reserve. This year, Secretary [of Energy] Granholm should complete the establishment of the reserve, begin a purchasing program, and buy American-produced uranium. We must maintain our ability to produce and process our own uranium.

In addition to losing our uranium producers, we are also losing our nuclear reactors. Currently, we have 94 operating nuclear reactors. These reactors provide 20 percent of our nation's electricity. Since 2013, 11 reactors have shut down. Even more are scheduled to retire by 2025, including five this year. Many of these plants could safely remain online for decades. While the reasons for these closures may be complex, too often they result in carbon emissions going up nationally and electricity reliability going down. That is why Senators Whitehouse, Crapo, Booker, and I introduced the American Nuclear Infrastructure Act. We did that last Congress. Among other things, the bill would keep reactors online that are at risk of closing prematurely. Last December, the Environment and Public Works Committee reported this bill with broad bipartisan support.

Innovation will also be key to re-establishing America's leadership in nuclear energy. Two years ago, President Trump signed into law the Nuclear Energy Innovation and Modernization Act. It is a bill I introduced along with Chairman Manchin and Senator Risch and others. This bill established a network for the Nuclear Regulatory Commission (NRC) to approve advanced nuclear reactor designs. Over the next decade, we expect advanced nuclear technologies to be deployed. New reactors will be safer, smaller, and more efficient. Advanced nuclear reactors will generate less nuclear waste, some may even run on previously used nuclear fuel. Advanced nuclear technologies will enable new market opportunities beyond the electricity sector. The heat from advanced nuclear reactors can drive a variety of industrial processes. It can improve the efficiency of chemical and hydrogen production. This heat can clean up wastewater and make salt water from our oceans usable. Advanced nuclear reactors will also improve access to materials used to diagnose and to treat diseases. They will even power missions to space.

The world is looking to nuclear power to meet its energy and environmental goals. We must ensure American technologies are leading in this global expansion of nuclear energy. American leadership in this sector is critical. It is critical to ensure nuclear energy is used safely for our peaceful purposes. Today, we will hear

directly from the industry executives working to maintain our historic leadership in nuclear energy. I look forward to the testimony.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Barrasso.

And now, let me welcome our highly qualified panel of witnesses for their opening statements.

Starting with Mr. Jeffrey Lyash, who is President and CEO of the Tennessee Valley Authority. Mr. Lyash, thank you for being here.

**STATEMENT OF JEFFREY J. LYASH, PRESIDENT AND CHIEF
EXECUTIVE OFFICER, TENNESSEE VALLEY AUTHORITY**

Mr. LYASH. Thank you, Chairman Manchin, Ranking Member Barrasso, and members of the Committee, and thank you for the opportunity to appear today and to represent one of the nation's largest and most innovative utilities and a corporate agency of the Federal Government, the Tennessee Valley Authority. My career began in the energy industry 40 years ago and it included service at the U.S. Nuclear Regulatory Commission and in both public and investor-owned utilities. I spent a significant portion of my career building, maintaining, and operating nuclear facilities and I believe that nuclear energy plays an important role in our nation's current and future energy supply. I appreciate the Committee's interest in this important resource.

TVA has a clear mission to serve the nation and the people of the Tennessee Valley. Our employees deliver on this mission by focusing on three mission-related areas: first, energy—low-cost and reliable; second, environmental stewardship—protecting and managing natural resources; and third, economic development—attracting and retaining jobs and capital investment. It's as powerful a mission as I have seen in my career and TVA funds this mission entirely from energy sales—no federal appropriations. As I look to the future, the alignment and interdependency of these three mission elements only grows stronger. Energy, environment, and the economy must move together and forward in balanced lockstep. A core TVA strength is our diverse and clean generating portfolio, one of the most diverse in the industry, including hydroelectric power, renewable energy, natural gas, a lessening contribution from coal, and the nation's third largest nuclear fleet. Our power system is one of the most reliable in the industry. We serve many rural communities over a seven-state region that is economically disadvantaged. So the price of electricity in our region matters. We have kept energy costs low and stable for most of the last decade and we intend to keep them flat.

Our system is also one of the nation's cleanest, with 60 percent coming from carbon-free sources last year. The aggregate of this supports quality economic growth in a region that is home to ten million people. In the past five years, TVA has helped deliver 341,000 jobs and over \$45 billion in capital investment to the region. Consistent with our environmental stewardship mission, we are a leader in carbon reduction, having already lowered our greenhouse gas emissions by 60 percent when compared to the 2005 benchmark. We accomplished this by incorporating renewable energy assets, replacing aging plants with new, high-efficiency nat-

ural gas and, importantly, expanding our nuclear program. We are committed to continuing this effort by executing our plan to reduce emissions 70 percent by 2030 and building a path using existing technology, including nuclear power to an 80 percent reduction. Of course, our aspiration is to achieve net-zero carbon emissions and to support broader, national efforts to decarbonize the economy. If we continue to lower greenhouse gas emissions without sacrificing cost and reliability, efficient electrification could be a key to decarbonizing other sectors of the economy. We already see this in the rapid development of electric transportation technology.

Electricity as a percentage of final energy has risen from three percent in 1950 to 21 percent in 2020, and studies project that this could be 40 percent by 2050. As electricity grows, so will customers' need for affordability and reliability, and our challenge is to lower existing fleet carbon emissions while adding reliable and affordable low-carbon resources to support electrification. Maintaining balance between price, reliability, electrical generation-sector CO₂ reduction, and efficient electrification will help deliver a sustainable economic advantage. Now, this will require investment in technologies such as energy storage, carbon capture, low-carbon fuels, and advanced nuclear design. Currently, 42 percent of TVA's total power supply comes from nuclear, and I believe that nuclear energy will play a critical role in our collective path to a net-zero carbon future. This large-scale energy source delivers reliability, cost effectiveness, and carbon-free energy, and its dispatchability, fuel stability and security, diversity, and its regional, positive economic impact is unmatched and, frankly, it's unrecognized in the organized market.

Optimizing and extending the operating lifetime of our nuclear fleet has to be a primary focus. We've already extended the lives from 40 to 60 years and we will shortly extend to 80, perhaps 100. But while extending the lives [of these reactors] is critical, it's not sufficient. TVA is actively engaged in developing new nuclear technology for tomorrow. Enabling new nuclear here will take innovation and creativity, but it also takes old school discipline and hard work. The momentum for new reactors is growing and that momentum can lead us to a diverse portfolio of advanced reactors to meet new needs. At TVA, we received an early site permit from the NRC for our Clinch River site. We're currently executing the environmental assessment process as the next step to establish this as a future option and our team is engaged with technology developers, including those that are here today to understand cost and risk associated with various reactor designs. When we begin site-specific engineering, it will be after an extensive and careful series of preparations. Our current schedule is to have a small modular reactor, perhaps in service, at Clinch River by 2032.

In summary, TVA has long been a leader in technology innovation. Nearly 90 years after our founding, pursuing new ideas and innovative solutions is an important part of everything we do. We believe nuclear technology plays a critical role in maintaining the necessary balance between price, reliability, generation-sector carbon dioxide reduction, and efficient electrification that will help deliver on our environmental goals and build sustainable economic advantage for the country.

Thank you. I look forward to answering your questions.
[The prepared statement of Mr. Lyash follows:]

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**Written Testimony of
Jeffrey J. Lyash
President and Chief Executive Officer
Tennessee Valley Authority
As submitted to the U.S. Senate Committee on Energy and Natural Resources
March 25, 2021**

INTRODUCTION

Chairman Manchin, Ranking Member Barrasso, and members of the Committee, thank you for the opportunity to appear today to represent one of the nation's largest utilities and a corporate agency of the federal government, the Tennessee Valley Authority (TVA).

I will mark my second anniversary as president and chief executive officer (CEO) of TVA next month. I am privileged and honored to lead the 10,000 women and men of TVA as we serve the nation and the communities and people of the Tennessee Valley region.

My career in the energy industry spans more than 40 years. I have worked both in public power and for investor-owned utilities. Before joining TVA, I was president & CEO of Ontario Power Generation, one of Canada's largest electric utilities with a diverse generating portfolio that included a large nuclear fleet.

Before that, I was president of CB&I Power, with responsibilities that included providing operating plant services for nuclear and other forms of generation. Formerly, I served in executive vice president capacities at Duke Energy and Progress Energy, and as the president and CEO of Progress Energy Florida. I spent a significant portion of my career building, maintaining and operating nuclear facilities.

I have held a Senior Reactor Operator's License issued by the U.S. Nuclear Regulatory Commission (NRC) and worked in a wide range of leadership roles at nuclear facilities including as operations manager, engineering manager, plant manager, and director of site operations.

Earlier in my career I served with the Nuclear Regulatory Commission in both technical and leadership positions.

I have a long career of active leadership in the electric power industry and in nuclear energy specifically. I believe that reliable and affordable electricity is foundational to our national security and our economy, that low carbon electricity will be critical to decarbonizing the broader economy, that a diverse portfolio of generating assets will best serve this objective, and that nuclear energy does now and must continue to play a vital role in our nation's energy supply. I appreciate the Committee's interest in this important resource.

TVA MISSION

TVA was established by Congress in 1933 and charged with carrying out a mission of service to the nation and to the people of the Tennessee Valley. Our unique, long-standing mission of service drives and inspires us daily to pursue new ideas and innovative solutions that improve our service to the communities and people we are privileged to serve.

TVA delivers on that mission through work in three key areas: energy that is low-cost and reliable; economic development that brings jobs and capital investment to the region; and environmental stewardship of the region's public lands, water and air. TVA was created with, and has continued to build on, its clear mission to benefit the public good.

This was our initial mission during the Great Depression. This was our mission while powering the nation to win World War II. This continued to be our mission during the subsequent decades of American growth and prosperity. And it is still our mission today.

The challenges are certainly different today than in 1933, but they are no less critical to the lives of those we are privileged to serve – delivering vital services and support across the region for almost 90 years, including during this unprecedented pandemic that continues to impact families, communities, businesses and industries. TVA's mission has stood the test of time.

THE PUBLIC POWER MODEL

TVA was established to serve the people of the Valley in partnership with local power companies, supplying public power at the lowest feasible rate for people throughout the region, from its largest cities to its most remote farms, and with an obligation to serve the people and their communities, not shareholders.

Together, TVA and local power companies ensure a reliable, clean and low-cost energy supply; a local presence and local voice; and the reinvestment of revenues into the energy, economic development, and environmental services that benefit the region. In this public power model, we now have new and stronger partnerships in place with 142 of the 153 local power companies we serve – 93% of them – and we are aligned around a 20-year commitment to plan and work together.

We also have strong relationships with our union partners. Over 60% of TVA's 10,000 employees are union members: over 6,000 annual employees and up to 3,000 hourly employees. A total of 17 unions represent TVA employees and contractors. In 2020, we entered into two historic agreements with our union partners – a 10-year extension of the recognition of the TVA Trades and Labor Council for Annual Employees as representing TVA craft employees, and a 10-year extension of TVA's project agreement with the North American Building Trades Union.

The TVA Retirement System administers retirement benefits for approximately 9,700 employees and 24,000 retirees and beneficiaries. Pension assets total \$8 billion; liabilities are \$13.6 billion; annual pension benefit payments total \$720 million; with a plan to be fully funded for TVA's pension liability by 2036. TVA implemented a plan in 2016 focused on fully funding the pension over a 20 year period. The plan includes assumptions around system demographics, contributions, asset returns, and discount rates. The funding plan is ahead of schedule, and we have shared details of this plan with the Office of Management and Budget. Separately, 401(k) plan assets total \$3.2 billion.

TVA'S OPERATION

TVA is the nation's largest public power supplier, providing energy that 10 million people across seven southeastern states rely on every day. We are also the nation's third-largest electricity generator and second-largest transmission system with 16,300 miles of high-voltage lines. TVA has one of the nation's largest, most diverse, and cleanest generating portfolios. Our portfolio includes hydroelectric, natural gas, coal, wind, and solar generation, as well as significant energy storage resources. In addition, and important to our discussion today, our portfolio includes the nation's third-largest nuclear fleet. In Fiscal Year 2020, our nuclear fleet generated 42% of the electricity delivered to our customers.

TVA-generated energy supports quality economic growth in the region with retail energy costs that ended calendar year 2020 lower than those at 79% of the nation's largest utilities, and industrial rates lower than those at 93% of other large utilities. The impact of a reliable, low-cost energy supply can be seen in the region's economic development successes. Over the past five years, TVA has helped attract or retain 341,000 jobs and more than \$45.4 billion in capital investment for the region. In 2020, despite pandemic conditions, we helped the region gain 67,000 jobs and more than \$8.6 billion in investment.

We manage the 652-mile Tennessee River system for multiple benefits, including flood control that prevented \$1 billion in flood damage last year as the region experienced 150% of normal rainfall. The river system consists of more than 40,000 miles of rivers, streams and tributaries; and it enables commercial navigation, water supply and water quality, recreation and other benefits for the region. Nearly 50 million tons of commercial goods move through the system of locks and dams each year, saving half a billion dollars in annual shipping costs.

We use TVA's 49 dams to manage lake levels and river flows in order to balance the competing demands on the reservoir system, and our hydro-electric dams are TVA's original energy source. The river and reservoirs also support a thriving recreation industry that produces almost

\$12 billion a year in economic activity, supporting more than 130,000 jobs and generating almost \$917 million in tax revenues to the region's state and local governments.

TVA's responsibilities for environmental stewardship also make us an important contributor to ongoing efforts to improve air quality in the region and the nation. From 1970 to 2020, TVA invested \$6.8 billion in environmental controls to reduce emissions from fossil-fueled plants. These investments have reduced our sulfur dioxide emissions 99% below 1977 levels. Nitrogen oxide emissions have been reduced 96% below 1995 levels. We have reduced greenhouse gas emissions by about 60% compared with the 2005 benchmark, one of the largest decreases in the power industry.

We do this with no federal appropriations of tax dollars. While TVA is a corporation of the federal government, TVA funds its power system and virtually all other operations entirely with revenues from energy sales and proceeds from debt issuances.

TVA was created in a time of great need for the nation – a time when new ideas and fresh approaches were essential to the economic recovery of the Tennessee Valley region. TVA and its broad mission represented a break with the past and a determination to bring new thinking to the problems at hand.

Those problems were vast. In 1933, personal income in the TVA region averaged \$3,500 a year in today's dollars – and just 45% of the national average at that time. Nearly two-thirds of Valley residents were farmers, and only 3% of them had electricity. Even fewer had running water. Valley lands were ravaged by erosion, overuse and wildfires. In some parts of North Alabama, three people in five had malaria. The Tennessee River was unmanaged, subjecting the region to devastating floods year after year while at the same time impeding transportation in areas of shallow water and treacherous shoals.

TVA was tasked with addressing a wide range of challenges, and its strategy focused on the innovative concept of managing the vast resources of the Tennessee Valley as an integrated system, across jurisdictional boundaries, to benefit the region as a whole. TVA engineers built a

network of hydroelectric dams to achieve multiple purposes – providing not only low-cost power but also flood control, transportation, water quality, and more. TVA scientists and educators developed and promulgated groundbreaking fertilizer technology that helped revive the Valley’s exhausted farmland and became the basis for 75% of the fertilizers used around the world. TVA engineers developed the nation’s first 512-kV transmission systems to reliably link TVA to a regional family of local power companies across 80,000 square-miles. And TVA economic development specialists pursued collaborative approaches to recruiting and retaining investments that would create and sustain quality jobs.

TVA’s commitment to developing and delivering new ideas transformed the Tennessee Valley region, leveraging the value of low-cost public power and going far beyond it, lifting the people of the Valley out of poverty and bringing the benefits of low-cost power to every community in the Valley.

In 2018, the region’s per capita income had risen to 82% of the national level. The Valley’s dependence on agriculture has shifted to an emphasis on industry, with only 0.5% of workers still employed in agriculture. TVA’s early efforts to reforest the region with 570 million seedlings restored large tracts of land to beneficial use. TVA’s integrated network of multi-purpose dams has averted more than \$9.5 billion in potential flood damage since 1936.

Today, TVA is applying the same spirit of innovation and forward-thinking that revolutionized life in the Valley to the emerging challenges of our time through our focus on six signature technologies:

- Energy storage integration
- Grid transformation
- Connected communities
- Advanced nuclear solution
- Decarbonization options
- Electric vehicle evolution

FOCUSING ON BUILDING A DIVERSE PORTFOLIO

As I highlighted, one of TVA's core strengths is our clean generating portfolio – one of the largest and most diverse in the industry. We have diversified our generating assets, modernized the system, lowered fuel costs, and reduced emissions.

We are a national leader in carbon reduction, the largest clean-energy producing utility in the Southeast, including our hydro generation, and home to nationally recognized solar programs. We have nearly 50% more clean generation than our closest regional peer, again, including our hydro generation, and currently have one of the lowest greenhouse gas intensities per unit of electricity produced in the U.S., with about 60% of our generation free of greenhouse gas emissions.

But we aren't satisfied. We are committed to continuing to reduce greenhouse gas emissions while maintaining our focus on delivering low-cost, reliable energy that our customers expect and deserve for the long-term.

TVA has maintained a Climate Change Adaptation Plan that was last updated in July 2020, and we are currently developing our Climate Action Plan for completion in the coming months. The goal of the adaptation planning process is to ensure TVA continues to achieve its mission and program goals and operate in a secure, effective, and efficient manner in a changing climate by integrating climate change adaptation efforts in coordination with state and local partners, tribal governments, and private stakeholders.

TVA manages the potential effects of climate change on its mission, programs, and operations within its environmental management processes. TVA has reduced greenhouse gas emissions from both its generation stations and its operations. Recent TVA Board actions have focused on TVA's 2019 integrated resource plan to balance its coal-fired generation by increasing its nuclear capacity, modernizing its hydroelectric generation system, increasing natural gas-fired generation, installing emission control equipment, increasing its purchases of renewable energy, building solar facilities, and investing in energy efficiency initiatives to reduce energy use in the

Tennessee Valley. Additionally, TVA has invested to increase energy efficiency in its operations. The combination of more stringent environmental regulations, lower natural gas prices, and lower demand for energy across the Tennessee Valley has reduced the utilization of coal-fired generation. These factors have supported the reduction in emissions from the TVA system.

Clean hydro power is TVA's original energy source, and we continue to invest in clean sources of energy, including solar. Our award-winning utility-scale solar program is setting a standard for the industry. Called Green Invest, this program utilizes a unique public/private partnership structure and competitive bid process that enable the growth of affordable solar without shifting costs to non-participants under the Valley Public Power model. Additionally, Green Invest leverages the demand for utility-scale solar from business and industry for economic development in our communities. We expect to add between 7,000 and 10,000 megawatts of solar over the next two decades. We are also adopting the resources and technology necessary to support the ongoing growth of solar, including about 300 megawatts of energy storage pilot projects that are in the works.

We are modernizing our gas generation fleet to help reduce emissions and support high levels of reliability, given the intermittency of renewables. And in partnership with multiple other utilities in the Southeast, we are working to establish the Southeast Energy Exchange Market. This market could potentially help all participants in the Southeast realize a higher penetration of renewables by creating a bilateral market to exchange energy efficiently.

As we supply reliable energy, the efficiency and security of our transmission system are critical. TVA works around the clock to monitor and protect its critical cyber assets, partnering with other government agencies, as well as with industry groups and peers such as the Edison Electric Institute and neighboring utilities.

TVA has a comprehensive cybersecurity program aligned to industry best practices that operates to predict, protect, detect and respond to threats. Our focus is being proactive and using risk-based assessments to protect TVA. In addition to having multi-layered threat

analysis capabilities, we perform continuous monitoring, penetration testing and vulnerability assessments.

TVA's critical systems are housed within a specialized, isolated network that is separated from corporate networks and inaccessible from the internet. This segmentation provides a significant added level of security.

TVA trains its employees to recognize and resist cyber threats and also adheres to an array of industry and government standards, including National American Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP) standards, Nuclear Regulatory Commission (NRC) security requirements and the Federal Information Security Management Act (FISMA).

As mentioned, our diverse generating system has helped us reduce our greenhouse gas emissions by about 60% from 2005 levels without negatively affecting customer prices or reliability. Our carbon-emission rate is 23% below our industry comparisons, based on the latest available 2019 data. Power rates and reliability are important to our customers, and our aspiration is to continue to lower our carbon emissions without affecting these critical metrics. In fact, we intend to hold energy costs flat for the next decade. Our reliability continues to serve our customers well, with 99.999% reliability since 2000. The value of that reliability was made clear just last month.

We saw the challenges that other parts of the country faced as a major winter storm made its way across Texas and other southern states in February. Millions of people were without electricity, many for several days; and the price of available energy during that time was extraordinary.

In the TVA region, the diverse generating portfolio we have developed served our customers well, as did our ongoing efforts to anticipate weather volatility and invest in winterizing our equipment. We have also increased our winter reserve margin from 20% to 25%, to better ensure uninterrupted service.

As a result, during the severe weather, the TVA power system delivered energy reliably, as designed, and at the cost we promised our customers, which is an effective rate lower today than it was 10 years ago. Our focus on investing in our system, maintaining stable rates, and taking appropriate actions goes back to our core principle of providing public power. We set rates as low as feasible, and we prioritize service to people and communities over profits.

The strength and value of the public power model can also be seen in TVA's response to the pandemic conditions of the past year. The value of public power and our commitment to serving local communities has been important during this challenging period.

Thanks to the outstanding efforts of TVA employees and employees of Valley local power companies, we were able to leverage TVA's strengths to ease the burden of pandemic conditions on the people we serve. After lowering rates in Fiscal Year 2020 for our local power company partners by 3.1%, in Fiscal Year 2021, our Pandemic Relief Credit is again reducing the wholesale energy bill for every local power company served by TVA, every large industrial customer we serve directly, and the large businesses and industries that are customers of our local power company partners.

This reduction is 2.5% each month throughout the fiscal year, putting \$200 million back into communities in the form of retail rate reductions, bill assistance for those in need, upgraded system infrastructure to maintain reliability, and more.

We are also providing Back-to-Business incentives for large industrial and commercial customers, investing \$12 million in credits so far to help businesses return to full operations and support economic recovery. To help local families and residents in need, we invested \$4 million in a Community Care Fund. With generous contributions of matching funds by local power companies and others, the Community Care Fund has provided almost \$8 million to help charitable organizations across the region address local needs through food banks, boxed-lunch programs for students, United Way, Boys and Girls Clubs, and other initiatives.

A SIGNIFICANT CHALLENGE AND OPPORTUNITY

Electricity is a significant portion of all the energy used in today's world, and that makes electricity a significant opportunity for decarbonization, as well. Electricity has grown from being just 3% of total final energy consumption in 1950 to approximately 21% of energy consumption in 2020.

If we continue to lower the greenhouse gas intensity of electricity without sacrificing reliability or low cost, electricity will be one of the keys to decarbonizing large sectors of the economy. Studies such as the Electric Power Research Institute's U.S. National Electrification Assessment predict that with efficient electrification, the contribution of electricity could rise to over 40% of final energy by 2050. As electricity's role grows, so will our customers' need for affordability and reliability.

We already see this in the rapid development of electric transportation technology. Electric utilities across the industry – working in partnership with the Edison Electric Institute – are supporting efficient electrification as a potentially cost-effective way to further reduce emissions, and transportation is the largest opportunity.

TVA and other utilities across the nation are working toward a clean energy transformation within their own vehicle fleets and through expanded networks of charging stations.

At TVA, we are partnering with the state of Tennessee to develop a statewide electric vehicle fast charging network. This network will power the growth of EVs across the state and increase consumers' confidence that they will have easy opportunities for refueling their electric vehicles. The first phase of this initiative, which targets achieving 200,000 electric vehicles in service by 2028, will reduce 1 million metric tons of CO₂ a year and save Tennesseans \$200 million a year in fuel expenses.

For TVA and other utilities, our challenge, and our opportunity, is to not only lower the carbon emissions of our existing fleets but also to increase the availability of reliable and affordable low

carbon generating resources to support this broader economy-wide electrification effort. If we fail to do so, we will not realize the potential benefits of efficient electrification.

Establishing and maintaining the right balance between price, reliability, electrical generation CO2 reduction, and efficient electrification will help deliver a sustainable, economic advantage.

NUCLEAR ENERGY LEADERSHIP

As TVA leverages the strength of public power, continues to improve our operations, and further reduces carbon emissions, we know that efforts to achieve net zero carbon levels will require the preservation and extension of our existing nuclear fleet and the development of new technologies. This includes the development of energy storage options at a price significantly lower than the current market; carbon capture and sequestration; and advanced nuclear technologies such as small modular reactors.

While preserving and extending our current nuclear assets is critical, it is not sufficient, in my view. A January 2020 study regarding zero-emitting resources performed by E3 notes significant increase in power costs to maintain electricity supply reliability, with advanced nuclear being the lowest-cost option when approaching 100% carbon-free sources of generation due to the intermittency of renewables and the amount of oversupply required without nuclear.

Nuclear energy will be critical to speed the process of decarbonization without overtly sacrificing reliability or costs, and TVA is an industry leader in expanding nuclear generation. In 2016, TVA brought online the first new nuclear generation of the 21st Century, achieving commercial operation of the second unit at our Watts Bar Nuclear Plant – gaining an additional 1,150 megawatts of carbon-free energy for our system.

Today, our nearly 8,000-megawatt nuclear fleet is the backbone of our clean generation portfolio. We are investing in our existing fleet to continue to improve safety, increase power output, and extend unit operating life. For example, our Browns Ferry Nuclear Plant in Alabama recently earned national recognition for its multi-year Extended Power Uprate project, which

contributes an additional 465 megawatts of carbon-free energy to the TVA system. As we operate our nuclear fleet safely and efficiently, we are also investing in maintaining and upgrading our plants to support extending plant life by decades.

SMALL MODULAR REACTORS AND ADVANCED NUCLEAR

As a leader in nuclear energy, TVA is engaged today in developing new nuclear technology for tomorrow, which we believe to be an essential component of TVA's and the nation's decarbonization efforts. Enabling and accelerating new nuclear will take innovation and creativity, as well as old-school discipline and hard work. As a known technology with decades of similar operating experience to rely upon, light-water reactors will remain a key enabler of our ability to decarbonize our nation's energy supply, especially in the timeframes proposed.

I am proud to say that nuclear utilities across our industry are taking on this challenge. In December 2019, TVA received the nation's first Early Site Permit for a small modular reactor from the U.S. Nuclear Regulatory Commission for two or more small modular reactors at our Clinch River Site in Oak Ridge, Tennessee. We are currently following the process related to evaluating the potential environmental impacts associated with deployment of more than one reactor and more than one design at the Clinch River Site to preserve our future options. Our team is actively engaged in technology assessment, working with technology developers to understand the costs and risks associated with construction and operation of various designs. When we select technology and begin site-specific engineering, it will be after extensive and careful planning and preparation.

In the past several years, the number of advanced nuclear designs under development has increased dramatically. The non-light-water designs hold promise. For these reactor types, more work needs to be done on fuel, supply chain development and NRC licensing; and the Department of Energy's recently announced Advanced Reactor Demonstration Program is an important supporting element. Development uncertainties for these designs, combined with the urgency to make meaningful progress toward decarbonization, led TVA to focus in the near-term on the next generation of small modular light-water reactor designs. We remain supportive of advanced reactor developers and want them all to be successful in order to provide long-term opportunities and competition in the energy marketplace. One non-light-water reactor developer has selected East Tennessee as its preferred location for a test reactor. While it does not have an NRC early site permit, we wish the project great success and look forward to supporting the developer.

As further development on this technology continues, it is important to look beyond the initial construction costs to the long-term costs associated with maintaining these important assets. While TVA does not believe a single-option, fully standardized design is in the best interest of the industry, we do believe that a larger adoption of fewer designs will create more benefits with lower operating and maintenance costs.

Overall, TVA believes nuclear technology plays a critical role in meeting electricity generation needs and carbon reduction goals in a manner that maintains reliability and keeps rates affordable. We believe light-water small modular reactors are the specific advanced nuclear technology most ready for deployment near-term.

TVA has the NRC-permitted Clinch River Site and a team doing the careful planning required to ensure that TVA has a viable option for this carbon-free resource available to the Tennessee Valley and the nation.

TVA's goal is to have a reliable, affordable, flexible and clean advanced reactor option available by 2032. Our path to this goal will be to make incremental investment decisions informed by continuous monitoring and analysis of our options. As mentioned, our Clinch River site is the only site in the nation with an NRC-approved early site permit for small modular reactors. This effectively eliminates a number of risks that have stopped or delayed many nuclear projects previously.

TVA has long been a leader in technology innovation and deployment in the electric power industry. We are applying this heritage to the new challenge of identifying the best options for the next generation of advanced nuclear. This is not a path that we can take alone. TVA is committed to partnering and collaborating with the many players who must be involved in this effort. Small modular reactors are ready for demonstration now – with the first commercial operation by 2030 possible, and multiple deployments possible in the 2030s. This would enable advanced nuclear to make a meaningful contribution to carbon reduction within the next two decades.

We will work to preserve and enhance the value of our Clinch River Site as a location to test and deploy new nuclear technologies. We will work with others in our industry to support policies, regulations and research that would further new nuclear development. And we will, through observation and some sweat equity, continue to monitor and support alternative technologies.

This comprehensive approach will increase the probability of TVA having a healthy array of options to meet our long-term decarbonization goals and perhaps move our nation closer to net-zero emissions at a cost everyone can afford.

CALL TO ACTION

Households typically spend 10% of their disposable income on energy; the greater availability of low-cost, reliable, clean electricity can lower that burden. More broadly, our collective goal should be to decarbonize energy generation and then to use this clean energy to reduce emissions across the economy through efforts such as TVA's electric vehicle initiative. Such improvements could be possible if we develop and use carbon-free nuclear energy as an essential part of our energy supply – electrifying the economy, driving down customer costs and eliminating carbon emissions.

In addition, a successful move into advanced nuclear technologies will reaffirm U.S. leadership in this important industry and potentially create opportunities to export U.S. nuclear products around the world as other nations confront these same environmental challenges.

With respect to new nuclear development, as with any new technology, there are challenges; and there are key needs that TVA and others must see satisfied before new nuclear moves forward:

- First, we must have the right product, one that is economically viable and competitive with other clean-energy alternatives.
- Second, we must take the right steps to reduce business and financial risks. Having the right amount of risk with first-of-a-kind nuclear is difficult. This requires us to identify and mitigate the risks during technology development and construction planning, so the project can be completed safely, on schedule and on budget and thereby build confidence for future projects.
- Third, we must have the right team, meaning a coalition of like-minded prospective partners who are committed to adoption of a specific technology that will achieve the needed operating and maintenance efficiencies over the life of the plant.
- Fourth, we must have the right business arrangements among the right participants. This would include the Department of Energy and industry participants who must share first-of-a-kind costs and risks so that ratepayers are properly protected.

At TVA, our first commitment is to the safe and efficient maintenance and operation of our existing nuclear fleet and other generating assets. Then, as we explore new nuclear technologies, we have the opportunity to demonstrate their worth to our region and the nation. TVA is hard at work on this front, and we already have some valuable assets to work with.

When TVA was founded in 1933, it was charged with developing technical solutions to address the economic and environmental challenges facing the people of the Tennessee Valley at the depths of the Great Depression. Since that time, TVA has become one of nation's leading electric utilities – and we have shared solutions across this nation and the world. Now, we have new economic and environmental challenges as the need for clean energy grows.

Together, TVA, the Department of Energy, and others have an opportunity to move toward an energy supply that is reliable and safe and supports long-term decarbonization goals for our region and the nation.

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The CHAIRMAN. Thank you, Mr. Lyash.
 Next we have Mr. Levesque, President and CEO of TerraPower.
 Mr. Levesque.

**STATEMENT OF CHRIS LEVESQUE, PRESIDENT AND CHIEF
 EXECUTIVE OFFICER, TERRAPOWER**

Mr. LEVESQUE. Thank you, Chairman Manchin, Ranking Member Barrasso, and members of the Committee. My name is Chris Levesque and I'm the Chief Executive Officer of TerraPower.

TerraPower was founded by Bill Gates and Nathan Myhrvold in 2006 to solve the dual challenges of the growing global demand for energy and the rising threat of climate change. Our mission is to improve nuclear energy delivery using 21st century technologies to increase safety, reduce costs, reduce the risks of weapons proliferation, minimize waste, and more efficiently use fuel. America is well-positioned to lead on advanced nuclear. TerraPower's goal is to provide a commercial product that provides reliable, zero-carbon, cost-effective energy solutions.

This is a critical period for nuclear power. Nuclear provides a majority of the clean energy in the United States. It is now America's second largest single source of electricity. But more nuclear plants are slated for closure than are currently being built. As the Intergovernmental Panel on Climate Change has noted, meeting aggressive climate goals requires expanding global nuclear capacity in the coming decades. This presents an opportunity for our industry both here and, importantly, globally, to meet this growing demand. Thankfully, the Committee recognizes it is time to demonstrate and deploy American advanced nuclear technology.

Last year, TerraPower was grateful to win a competitive award for the Advanced Reactor Demonstration Program, a program authorized by this Committee, to demonstrate our Sodium technology. Sodium is designed to meet the energy needs of the 21st century electrical grid, which is facing growing resiliency challenges as fossil plants are retired, and clean but intermittent sources like wind and solar are deployed in mass. Sodium not only generates clean energy at 345 megawatts rated electrical output, it could also store heat from our reactor in a molten salt storage system, allowing it to deliver 500 megawatts of power for five and a half hours. Such storage capability is four times greater than the largest lithium battery storage system in the world. It allows Sodium to work well with renewables, like wind and solar. This is a benefit because as more utilities plan to dramatically reduce or even eliminate emissions and pollution from their power systems, they need firm, dispatchable power and hours-long storage capability that batteries cannot economically provide.

We are confident that Sodium's cost and safety profiles will make it an attractive option for utilities around the world. Sodium's novel architecture provides significant improvements in safety. Instead of water, Sodium uses sodium as our coolant, which has a boiling point of 882 degrees Celsius. Unlike conventional reactors, Sodium operates at atmospheric pressure and its operating temperature is hundreds of degrees below the boiling point of the coolant. This greatly reduces the likelihood and, importantly, the severity of any accident. Our design relies on natural

forces, like convection to cool the reactor after an unexpected shutdown. Because inherent safety is built into the reactor design, we are able to reduce the number of man-made systems needed to ensure safety, which results in cost savings. In addition, the Sodium architecture separates the energy storage and electricity production systems from the nuclear island, allowing us to further decrease costs.

The Committee has also recognized the role the Federal Government can play in developing advanced nuclear technology, like it has for civil nuclear advances over the past half century. Companies like TerraPower and X-energy have spent many years and hundreds of millions of dollars to develop our technologies. The Advanced Reactor Demonstration Program (ARDP), which establishes a 50/50 cost share program to build the first commercial-scale units to demonstrate the technology, comes at a critical moment. If Congress continues to fully fund the ARDP, we will have multiple advanced reactors, fully demonstrated and commercially available in the late 2020s—reactors that will help the United States decarbonize, create good, high-paying jobs, and allow our country to re-establish leadership, strengthening our nation's security. We urge Congress to continue funding the ARDP at the levels required to demonstrate both of these reactors under the timeframe Congress mandated.

TerraPower appreciates the Committee's bipartisan support for nuclear. Do recognize that the country that owns the advanced nuclear transition will be a leader in the global nuclear market. As countries around the world turn to nuclear energy for reliable, clean, and abundant energy, we will have American technology options to offer them. I look forward to taking your questions.

[The prepared statement of Mr. Levesque follows:]

**Chris Levesque, President and Chief Executive Officer
TerraPower**

**United States Senate
Committee on Energy and Natural Resources**

Hearing on Nuclear Energy

March 25, 2021

Thank you, Chairman Manchin, Ranking Member Barrasso and members of the Committee. My name is Chris Levesque, and I am the Chief Executive Officer of TerraPower, an advanced nuclear technology company.

Including the past 6 years at TerraPower, I have spent my entire career working in nuclear energy, beginning with my service in the US Navy on submarines. I have also had the opportunity to work on civilian nuclear projects in the US and internationally. These experiences greatly inform my comments today, as well as my belief that the US must retain its leadership in nuclear energy technology.

In 2006, our company's founders - Bill Gates and Nathan Myhrvold – began looking for a technological solution to the dual challenges of the growing global demand for energy and the rising threat of climate change. A key tool, they discovered, is advanced nuclear technology.

The mission of advanced nuclear energy companies like TerraPower is to improve nuclear energy technology on a number of fronts, using the capabilities offered by 21st century technologies and digital modeling previously unavailable. These technologies move well beyond our country's 20th century fleet of light water reactors, including safety improvements, reductions in the risk of weapons proliferation, minimization of waste production, more efficient use of uranium supplies and lower costs. We believe that we, as an American company, have a duty to innovate in clean energy. No other country has the capacity for innovation, and the freedom and cross-discipline capabilities to think innovatively, like the United States. We benefit from the investments made by past Congresses, and the work of the engineers and scientists who have gone before us. TerraPower's goal is to provide a commercial product that provides reliable, zero-carbon, cost-effective electric and thermal energy solutions that can be deployed in the United States and abroad.

Last year, TerraPower was grateful to win a competitive award from the Advanced Reactor Demonstration Program to demonstrate our Natrium technology, which we developed in partnership with GE-Hitachi. Natrium is specifically designed to meet the needs of a twenty-first century grid. Natrium uses the heat from our reactor to power a molten salt storage system that allows the system to store 500MWe of power for five and a half hours, making it four times larger than the largest lithium battery storage system in the world. This allows Natrium to work well with variable renewables like wind and solar. This is beneficial because, as more utilities plan to dramatically reduce, or even eliminate, emissions and pollution from their power system, they need firm dispatchable power in addition to renewables to meet rising demand.

While we are confident these attributes will make Natrium attractive to customers, we know that any nuclear reactor will also need to be both safe and cost effective. Because of our novel architecture, Natrium provides significant improvements in safety over conventional designs. Instead of water, Natrium uses sodium as our coolant which has a boiling point of 882 degrees Celsius. Unlike conventional reactors, Natrium operates at atmospheric pressure and its operating temperature is hundreds of degrees below the coolant boiling point, which greatly reduces the likelihood of a significant accident. Our design relies on natural forces, like convection, to cool the reactor after an unexpected shutdown. Because inherent or natural

safety is built into the reactor design, we are able to reduce the number of man-made systems needed to ensure safety, which results in significant cost savings. In addition, the Natrium design also separates the energy storage and electricity production systems from the nuclear island, which allows us to further decrease costs. We are confident that Natrium's cost and safety profiles will make it an attractive option for utilities around the world.

But getting this product to market will be surely helped by the actions this Committee has taken to support the demonstration of advanced reactors like Natrium. Companies like TerraPower and X-Energy have spent many years and hundreds of millions of dollars to develop our technologies. However, Congress's authorization of the ARDP, which establishes a 50/50 cost share program to build the first commercial scale units to demonstrate the technology comes at a critical moment. Like all peaceful, civil nuclear technology advances over the past half century, today's new reactor designs need government support to reach commercialization. If Congress continues to fully fund the ARDP, we will have multiple advanced reactors fully demonstrated and commercially available in the late 2020s. These tools will help the United States decarbonize, create good, high paying jobs, and allow our country to reestablish leadership in an industry critical to our nation's security. We urge Congress to continue funding the ARDP at the levels required to demonstrate both of these reactors under the timeframe Congress mandated.

The Role of Advanced Nuclear in Meeting Ambitious Climate Goals.

The Committee has explored the need for the federal government to address climate change; nuclear technology is a key tool in solving that problem. The United Nations' Intergovernmental Panel on Climate Change (IPCC) provides a number of pathways to keep global emissions below 1.5 degrees Celsius. None of those pathways allow for a reduction of the share of global power provided by nuclear, and the high economic growth scenario – the one that lifts billions out of poverty – calls for global nuclear power demand to increase by five times current levels.¹

Nuclear is a key part of the plans of many states and utilities to reduce or eliminate emissions from the power sector. Like wind and solar, nuclear power is carbon-free. And like coal and natural gas, nuclear power can provide power 24 hours a day, 7 days a week. But unlike coal and natural gas, nuclear neither emits carbon dioxide or other air pollutants, nor does it require continual delivery of commodities to produce power. The result is always-available, carbon free power that does not require a natural gas pipeline or a coal train to operate, and can operate in increasingly volatile weather conditions. No other form of power has all these attributes.

We also know that we need to decarbonize the power sector quickly. Nuclear is the only option that can scale fast enough to address the urgency of this need. We saw the benefits of rapid deployment from 1969 to 1990 when the U.S. built more than 100 nuclear plants. Rapid build and heavy investment in research and development were primary contributors to the stable, emissions-free power that cleared pollution from our cities and fueled growth.

¹ https://www.iph/site/assets/uploads/sites/2/2019/02/SR15_Chapter2_Low_Res.pdf

In addition, as the Committee knows, getting to a 100 percent carbon free future will require us to eliminate emissions in more difficult to decarbonize sectors of the economy like industry. We will have to develop strategies to produce chemicals, cement, metals and other products without burning fossil fuels. Advanced nuclear technologies like ours can provide reliable, very high temperature heat for industrial processes. Our designs can provide heat in excess of 500 degrees Celsius without emitting any carbon dioxide or methane.

The Economic Case for Investing in Advanced Nuclear

These attributes are good for the environment, but also present substantial economic opportunity for our country. Today, most Americans either live in states with emissions targets or are served by utilities who have put forth ambitious emissions goals. While variable renewable technologies like wind and solar are becoming the lowest cost options for the next-kilowatt-hour of new generation, getting to a completely decarbonized system will require firm, flexible zero carbon sources of energy that can produce power at all hours of the day. Our home state of Washington passed an ambitious climate law that will require us to achieve zero emissions in the power sector. Energy Northwest commissioned a study by the consulting firm E3 which found, that to reach that goal, including new nuclear in addition to massively increasing wind, solar and storage penetration would reduce the cost to ratepayers by nearly \$8 billion per year.² While wind and solar continue to get cheaper, zero carbon dispatchable power is incredibly valuable for achieving decarbonization goals.

More and more corporations also are committing to bold climate goals, including two powerhouse global companies headquartered in our home state—Microsoft and Amazon. Microsoft has promised to become carbon negative by 2030, removing more carbon than it emits, and by 2050 it has vowed to erase a volume of carbon equal to all of the greenhouse warming gas that the company has emitted since launching in 1975. Amazon has pledged to reduce its carbon footprint by investing in electric vehicles, reforestation projects and to achieve net zero annual carbon emissions by 2040.

Globally, every potential export market in the world has signed onto the Paris Climate Agreement. To meet the Paris goals, those countries will need energy sources with attributes like advanced nuclear. And our case in these markets mirrors the economic case here. In December, the International Energy Agency noted that “new nuclear power will remain the dispatchable low-carbon technology with the lowest expected costs in 2025.”³ As more countries make more ambitious pledges, the market for advanced nuclear will grow.

We are excited about the domestic market for our products, but it’s hard to overstate the potential of the global market for firm, carbon free energy technologies like advanced nuclear. Given that, it should not be surprising that other countries are working to develop advanced nuclear technology. Countries like China and Russia are actively supporting the development of advanced reactors with significant direct investment by government into state-supported companies. This direct government support helps these countries establish a valuable export

² <https://www.powermag.com/energy-northwest-study-makes-a-case-for-smrs-in-future-power-mix/>

³ <https://www.iea.org/news/low-carbon-generation-is-becoming-cost-competitive-nea-and-iea-say-in-new-report>

product, but the sale of a reactor also brings important national security benefits for those governments. Some of these state-supported companies sell their reactors with a multi-decade contract to provide fuel, operations and maintenance and waste services. This creates a multi-decade strategic partnership between the country selling nuclear reactors, and the country purchasing that technology. Russia, for example, is currently offering these “Build, Own, Operate” contracts in Europe and the Middle East.⁴ Those contracts will enable Russia to increase its influence in those regions.

Additionally, the investment in nuclear technology yields applications that go beyond energy. Because of the technical expertise we’ve gained from working to build reactors, TerraPower is working with Oak Ridge National Laboratory to separate life-saving medical isotopes from cold war era nuclear waste currently stored in Tennessee. These rare isotopes can be used to attack cancer cells without damaging surrounding tissue and could lead the way to dramatic improvements in cancer treatment.

Civil nuclear technology was invented in the United States, as was every advanced nuclear technology currently under development across the globe. Our nation should benefit from that investment, both in terms meeting our domestic clean power needs, and in terms of the economic and national security opportunity for American companies to sell their products around the world.

What is Advanced Nuclear, or “Generation IV?”

Light water reactors have served us very well, but new designs can improve fuel cycles, proliferation, safety, and the cost of light water technologies. TerraPower’s designs, including Natrium, are walk away safe, and use natural forces like gravity and air cooling, not human intervention, to keep the reactor safe when faced with unplanned events. Our Natrium plants can reduce heavy metal waste volume over conventional designs by two-thirds and future Natrium units that can run on natural or depleted uranium by 80 percent. Because of reduced enrichment needs, and because more of the fuel is burned in the reactor core, the risk of proliferation is significantly reduced. These improvements make our reactors safer, cheaper, and able to operate with lower volumes of waste.

In the nuclear industry, safety is always our first and highest priority. Regulators and operators globally share experiences allowing knowledge transfer broadly across the industry, and virtually every meeting in the industry starts with a conversation about safety. Safety is deeply ingrained in the nuclear industry’s culture. As a result, nuclear power has consistently proven to be the safest way to make electricity, with a lower mortality rate per terawatt hour of power produced than any other source of power⁵. America’s nuclear reactors have a tremendous record in terms of operating safely, and safety is at the core of our advanced reactor designs.

Advanced designs build on that success. Advanced reactors offer next-generation safety benefits that permit new applications and expand the potential to use nuclear energy for more

⁴ <https://www.belfercenter.org/publication/russian-nuclear-energy-proposal-offer-you-cant-refuse>

⁵ <https://www.statista.com/statistics/494425/death-rate-worldwide-by-energy-source/>

than electricity production. Like other advanced designs, Natrium will not require active safety systems, eliminating the need for diesel engines, multiple back-up systems and human intervention under emergency scenarios. Natrium also avoids high pressure and relies on the natural laws of physics to maintain the safety of the plant without needing operator intervention or auxiliary power, using air and the properties of natural convection, rather than water, as the ultimate heat sink. Safety features in the selection of fuels and coolants provide for enhanced versatility and allow for flexibility in siting a reactor as sites can be much more compact with a smaller emergency planning zone within the site boundary. If you compare these reactors to the one in Fukushima, there would not have been an accident. A fast reactor like Natrium would have shut itself down independently, indefinitely.

We also know that our potential customers are very concerned about the cost of nuclear. We are too, and our reactor is specifically designed to reduce cost. Because of our passive safety designs, TerraPower's advanced reactors have less of a need for multiple, redundant safety systems. Our advanced reactors operate at higher temperatures and burn more of the fuel, yielding more electricity and lower costs per kilowatt-hour for the same plant size. Our reactors also require less maintenance and fuel, and as we move beyond our demonstration design, we have the potential to make up to 30 times more energy out of each ton of natural mined uranium used to provide carbon free power. Eventually, we envision that our reactors can run on depleted uranium - waste product from enrichment that is currently managed by the U.S. Government. These attributes result in substantial savings over light water designs.

Finally, we know that America's energy system is going through tremendous change. Tomorrow's grid will rely heavily on wind and solar. Natrium is specifically designed to integrate into a grid with high levels of variable renewable penetration. Natrium will use the high temperature heat from our reactor to power a molten salt storage system that can store tremendous amounts of energy, levels of magnitude larger than the energy stored by typical battery storage facilities. That energy can be used to power the grid at peak demand when the wind isn't blowing, or the sun isn't shining. We view our technology as a key enabler of wind and solar technologies, and part of the fastest way to get to the 100 percent clean energy future envisioned by the Committee.

U.S. nuclear technologies and research and development capabilities are envied around the world, and the U.S. enjoys close political and commercial relationships with many countries forged over decades through the construction of U.S.-origin nuclear plants. Exports of U.S. nuclear technology allow the U.S. to set global standards for nuclear security, safety and nonproliferation. New designs will enable advanced nuclear to fit seamlessly into systems with high penetrations of variable renewable sources. U.S. nuclear innovators, including TerraPower, have advanced their technology readiness levels sufficiently for demonstration and offer substantial advances in economics, safety and proliferation resistance. Now is the time to build on the momentum of these innovators, demonstrate advanced reactors, and deploy this important tool in the fight against climate change. I thank the Committee for its leadership in helping to get us to this critical point in the technology's development.

The Role of the Federal Government

Unlike many of our foreign competitors, America's advanced nuclear industry is made up of private companies backed by private investors who partner with our national laboratories, research universities, and agencies, like the U.S. Department of Energy, to develop domestic advanced nuclear technology.

Clean energy technologies have long benefited from partnering with the federal government to make it through the "valley of death" that new technologies face initially. Wind and solar are no exceptions and would not have taken off without subsidies, power-purchasing targets and government funding for research and development activities. The result is clean technology innovations with reduced costs and faster development and deployment timelines than previously imagined. This is especially the case for technologies like advanced nuclear that are expensive to demonstrate.

As such, we were ecstatic that Congress picked up on the work of this Committee in authorizing and funding the Advanced Reactor Demonstration Program in the FY2020 and FY2021 Appropriations bills and the Energy Act of 2020. We were equally pleased that Natrium was selected alongside the X-energy's Xe-100 as winners of the ARDP demonstration competition. We thank the Department of Energy for selecting two truly advanced designs and we are committed to meeting the ambitious demonstration schedule outlined by Congress. Having these two advanced technologies available to the market will play a key role in meeting America's environmental, economic, and national security goals.

Given the importance of the ARDP to America's future, we are humbled to be a partner with the federal government in bringing Natrium to market. As we begin work on our ARDP demonstration projects, the most important thing Congress can do is to ensure the federal cost share for these projects is available each year. As is the case with any megaproject, the cost and schedule for these projects will follow an S-curve, with funding increasing in each of the first five years, and then tailing off for the last two years. Unlike a traditional R&D program, this will require sustained budget increases for the next few years. We know that Congress is serious about meeting an aggressive timetable, and we are too. And while this project is a big undertaking, we are prepared to meet our half of the cost-share agreement going forward. We will need Congress to ensure that the federal government can meet their share as well.

In addition, we appreciate the efforts of the committee to ensure the availability of High Assay Low Enriched Uranium (HALEU) to customers like TerraPower. Like most advanced designs, we will require HALEU to run our demonstration reactor. HALEU will be necessary to fuel our reactors and we appreciate your efforts to ensure the availability of HALEU for our growing advanced nuclear industry.

Conclusion

TerraPower very much appreciates the broad bipartisan support nuclear power has received from this Committee and is grateful that you all have set advanced nuclear technology on a path to play a key role in America's energy future. The country that owns the advanced nuclear

transition will be a leader in the global nuclear market and empower countries around the world to ensure access to reliable, clean and abundant energy. The advanced nuclear industry is critical to providing the safe, emissions-free, firm power the world will require over the coming century.

We know America can lead in nuclear innovation. In 1957, the Shippingport Atomic Power Station - the world's first full-scale commercial nuclear power plant, came online in Pennsylvania. Shippingport was the cornerstone for commercial light water reactor technology and led to the construction of hundreds of reactors around the world employing U.S. born technology. In the coming decades, many new countries will employ nuclear energy for the first time to meet their growth needs. China and Russia stand poised to supply these countries with their technology. The U.S. needs to be ready with ours. It is time to repeat the story of Shippingport, this time with next generation technology that can help bring clean power to the United States and around the world. This must happen if we are to meet the goal of a 100 percent clean economy.

Our company was founded on the premise that we must end both global energy poverty and solve climate change. We believe that we can provide safe, reliable, cost-competitive advanced nuclear technologies that can help meet those difficult challenges. We also know that this committee is no stranger to tough problems, and bold solutions. And we appreciate everything you have done to help bring advanced nuclear technology to market. We look forward to working with you as we begin building the first Sodium reactor as a part of the Advanced Reactor Demonstration Program.

On behalf of TerraPower's nearly two hundred employees working to make that goal a reality, thank you for the opportunity to appear before the Committee.

The CHAIRMAN. Thank you, Mr. Levesque.

And next we have Mr. Scott Melbye, President of the Uranium Producers of America.

Mr. Melbye.

STATEMENT OF SCOTT MELBYE, PRESIDENT, URANIUM PRODUCERS OF AMERICA, AND EXECUTIVE VICE PRESIDENT, URANIUM ENERGY CORP

Mr. MELBYE. Thank you, Chairman Manchin and Ranking Member Barrasso. It is an honor to testify before the Senate Energy and Natural Resources Committee. I am a second-generation American uranium miner and currently President of the Uranium Producers of America and Executive Vice President of Uranium Energy Corp, with operations in Texas and Wyoming. I have 36 years of experience in every facet of the international nuclear fuel cycle, from the production and global marketing of uranium to its use as clean energy fuel in the Palo Verde Nuclear Station near Phoenix, Arizona.

This is an exciting time for nuclear, which is already providing electricity in one in five American homes and over half of our nation's carbon-free power. Nuclear power can work hand-in-hand with other green technologies, like wind and solar to help advance the American clean energy revolution. But the United States must establish its global nuclear leadership, including a robust nuclear fuel cycle that has been eroded by Russia, China, and state-owned entities in recent years. America is dangerously close to losing our uranium fuel industrial base. We lack a domestic enrichment capacity, free of control by foreign powers. The sole U.S. conversion facility in Illinois has been idle since 2017 and will restart operations in 2023. We are nearly completely dependent on foreign uranium imports, state-owned entities in Russia, Kazakhstan, and Uzbekistan, for supplying almost half the fuel used by America's reactor fleet. And Chinese state-owned entities are capturing large portions of global uranium mining capacity, taking supply out of the free market and putting it under Beijing's control.

Uranium is also required for naval propulsion and nuclear deterrents, the pure essence of what it means to be a critical mineral. The 93 small modular reactors in our fleet of 82 aircraft carriers and submarines have defended our interests safely and reliably since the 1950s. These reactors must rely on U.S.-origin uranium, which is unobligated to the controls of foreign nations, and we need to retain our ability to independently refuel them. TVA's tritium production and Department of Defense microreactors have similar domestic uranium requirements. Absent a renewed commitment to America's nuclear fuel cycle, we are jeopardizing our defense capabilities and our clean energy goals. Russia and China fully leverage energy dominance to their geopolitical advantage. They're playing a long game in a way America is not, using their nuclear energy clout to strengthen geopolitical ties with energy-starved countries around the world. America is also risking its seat at the global non-proliferation table.

The similarities to our rare earth mineral dependence on China are startling, but it doesn't have to be this way and it isn't too late. We have over one billion pounds of uranium in known and likely deposits in the United States. With 21st century conventional min-

ing practices and environmentally friendly in situ uranium recovery technology, the modern uranium mining industry is very different than was the case back in the 1950s. We are highly regulated and have embraced, for many reasons, the world's highest health, safety, and environmental protection standards, and we are cost-competitive globally, but for the price undercutting tactics of state-owned companies. With swift action to implement the strategic uranium reserve, the Department of Energy can take advantage of the licensed infrastructure and human resources we still have on standby. Congress recently appropriated \$75 million for the uranium reserve on a bipartisan basis, and with the support of nuclear utilities, it is crucial the Department move quickly to begin purchasing uranium this year. This will preserve the industrial base, guard against global supply disruptions, and create a source of U.S.-origin uranium for defense needs. We urge Congress to grant the full funding recommended over the next ten years by the interagency Nuclear Fuel Working Group led by the Department of Energy. One hundred fifty million dollars a year is a modest investment, considering it will preserve the nuclear fuel cycle in the U.S. instead of ceding it to China, Russia, and their allies.

In closing, I applaud this Committee for exploring ways to advance America's nuclear leadership and capabilities in support of clean energy goals, national security, and our global competitive presence. I look forward to taking any questions that you may have.

[The prepared statement of Mr. Melby follows:]



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STATEMENT OF SCOTT MELBYE
President, Uranium Producers of America
Executive Vice President, Uranium Energy Corp

March 25, 2021

BEFORE THE

U.S. SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

FULL COMMITTEE HEARING ON NUCLEAR ENERGY

I. INTRODUCTION

My name is Scott Melbye and I am the Executive Vice President of Uranium Energy Corp (UEC) with operations in the states of Wyoming and Texas. As a second-generation American uranium miner, I am proud to serve as the President of the Uranium Producers of America (UPA), the trade association representing the domestic uranium mining and conversion industry. It is an honor to testify before the Senate Energy and Natural Resources Committee on restoring American leadership in the global nuclear energy industry. I have been fortunate to have been involved in the nuclear industry for the past 36 years in every facet of the international fuel cycle from the production and global marketing of uranium to its use as clean-energy fuel in the three-unit Palo Verde Nuclear Station near Phoenix, Arizona.

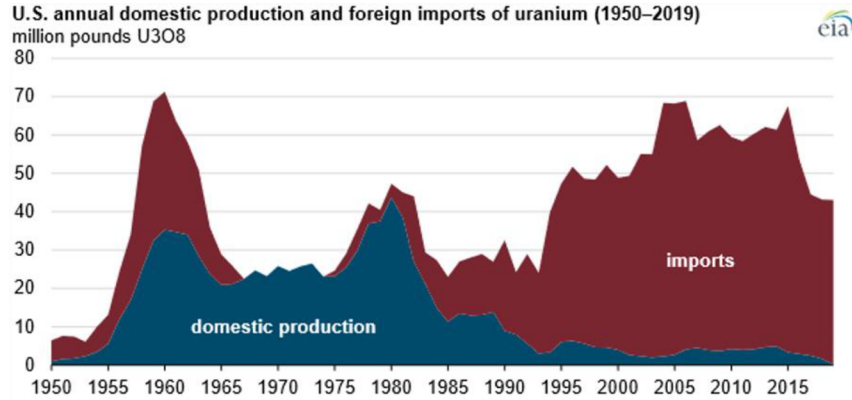
UPA's mission is to promote the viability of the nation's uranium industry, while being good stewards of the environments in which we work and live. UPA members conduct uranium exploration, development and mining operations in Arizona, Colorado, Nebraska, New Mexico, Texas, Utah, and Wyoming. Our membership also includes the lone remaining conversion facility in the United States in Illinois and the last operating conventional uranium mill in the United States in Utah. The UPA is committed to the preservation and expansion of America's capacity to produce its own uranium in support of clean energy and national security objectives.

This is an exciting time for nuclear energy, which is already providing electricity to 1 in 5 American homes and businesses and over half of our nation's carbon-free power. With the incredible potential of small modular and advanced reactors, nuclear power can work hand in hand with other green technologies, like wind and solar, to lead the clean energy revolution. But to fully unlock nuclear power's ability to help us achieve our clean energy goals, the United States must re-establish its global nuclear leadership, including restoring a robust domestic nuclear fuel cycle that has been eroded by Russia, China, and state-owned uranium production entities in recent years. Building on Congress' recent appropriation to begin uranium purchases to fill the Strategic Uranium Reserve by ensuring full funding for the program moving forward is a necessary step towards ensuring our nuclear energy self-sufficiency.

II. STATE-OWNED ENTITIES THREATEN U.S. CLEAN ENERGY SELF-SUFFICIENCY

America is dangerously close to losing our uranium fuel cycle expertise and industrial base. We currently lack a domestic uranium enrichment capacity that is completely free of control by foreign powers. The sole remaining U.S. conversion facility, located in Illinois, has been idle since 2017 and will restart full operations in 2023. U.S. nuclear utilities are almost completely dependent on foreign imported uranium and the uranium mining industry is on the verge of disappearing.

The U.S. was once a global leader in uranium production, producing more than 40 million pounds annually in the early 1980s at a time when the domestic industry employed more than 21,000 Americans. Despite the existence of vast uranium resources in the United States, the lack of commercial purchasing of domestic uranium has driven production and employment to historic lows not seen since the dawn of the industry in the 1940s. U.S. uranium production in 2019 fell to 174,000 pounds, the lowest amount since the U.S. Energy Information Administration (EIA) began collecting this data in 1949. This is only a fraction of the material needed to power even one of the United States' 94 commercial nuclear reactors. The EIA's quarterly reports for 2020 have continued to show record low production levels.



As the domestic industry has been forced to downsize, we have lost considerable talent and expertise that will become increasingly difficult to replace. Operating these facilities requires trained, experienced, and skilled engineers, geologists, scientists, technicians, and operators. Several of these facilities are in economically challenged regions. However, EIA reports that the total employment in the uranium mining and milling industry is approximately only 265 people as total employment fell by over 83% between 2008 and 2019.¹

Price-insensitive imports from state-owned entities (SOEs) threaten the continued existence of the U.S. domestic industry, especially uranium imported from the countries of the Former Soviet Union (FSU) – Russia, Kazakhstan, and Uzbekistan. In response to adverse market conditions, U.S. mine production of uranium dropped more than 95 percent between 2010 and 2019.² This was not the case from SOEs; they ignored the market, increased their total supply, and further suppressed prices at the expense of free market competition in the United States, Canada, and Australia. SOEs engage in predatory pricing designed to drive competition out of a market. The Department of Commerce’s June 2020 Post Preliminary Analysis Memorandum regarding the Russian Suspension Agreement determined that Russian imports to U.S. utilities were contributing to the suppression and undercutting of domestic price levels.³

U.S. companies are not competing with free market companies in the FSU; we are competing with their governments who are taking advantage of our free market system. Displacing U.S. supply, imports from SOEs in Russia, Kazakhstan and Uzbekistan have averaged over 40 percent of U.S. commercial reactor requirements since 2010. As of 2019, uranium imports from

¹ 2019 Domestic Uranium Production Report, EIA May 2020, Table 6

² 2019 Domestic Uranium Production Report, EIA May 2020, Table 9

³ Post Preliminary Analysis Memorandum in the 2017 – 2018 Administrative Review of the Agreement Suspending the Antidumping Investigation on Uranium from the Russian Federation, Joseph A. Laroski Jr., U.S. Department of Commerce, June 17, 2020

the FSU climbed to over 47 percent of U.S. reactor demand, the highest percentage over the last decade.⁴

Chinese SOEs are also working to increase their share of the global market. Chinese entities own large inventories and subsidize large uranium mines that are expanding production despite having costs that are far above the current market price of uranium. When a Chinese government-backed entity takes a controlling interest in uranium mines, as it has done in Africa for example, this takes supply out of the free-market and puts it under Beijing's control. This is reminiscent of China's success in taking control of other critical supply chains, such as rare earth elements. Data from the International Trade Commission (ITC) show that imports of enriched uranium from China have been occurring since 2015 and U.S. nuclear utilities have spent more than \$200 million on Chinese enriched uranium.⁵ Expanding Chinese enriched uranium imports would further displace U.S. uranium supply.

Russia and China leverage energy dominance to their geopolitical advantage. The federal interagency Nuclear Fuel Working Group's (NFWG) April 2020 report stated: "The ability of foreign state-owned enterprises to utilize the nuclear fuel cycle to establish dominant market positions and enduring bilateral relationships can pose significant geopolitical challenges for the United States."⁶ The NFWG further stated that "[t]his reality threatens American energy security, narrows or eliminates foreign policy options and erodes American international influence to set strong non-proliferation, safety and security standards ... Russia – a nation that has 'weaponized' its energy supply as an instrument of coercion – dominates nuclear markets." Russia and China are playing a long game in a way America is not, using their nuclear energy clout to strengthen geopolitical ties with energy-starved countries around the world.

III. DOMESTICALLY MINED URANIUM IS CRITICAL FOR CLEAN ENERGY SECURITY AND NATIONAL SECURITY

The U.S. Department of the Interior defines uranium as a critical mineral "essential to the economic and national security of the United States, the supply chain of which is vulnerable to disruption, and that serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economy or national security." Nuclear energy provides 20 percent of our electricity and over half of our carbon-free power, bolstering clean air initiatives across the country. The domestic uranium infrastructure and nuclear fuel supply chain are crucial for today's fleet of commercial nuclear reactors as well as the nuclear technologies of the future.

Uranium is also key to our naval propulsion program and nuclear deterrence, underpinning its status as a critical mineral. The small modular reactors in our fleet of aircraft carriers and submarines have defended our interests safely, efficiently, and reliably for decades. These reactors must be fueled by U.S.-origin uranium that is unobligated to the controls of foreign nations and we must retain our ability to independently refuel them. The production of tritium at the Tennessee Valley Authority (TVA) also requires U.S.-origin uranium, as would the fueling of small modular reactors and micro-reactors under consideration by the U.S. military to provide more secure and resilient power sources for military facilities. Absent a renewed federal commitment to a robust

⁴ EIA Uranium Marketing Annual Reports - Tables 3 and 18

⁵ Imports of Uranium Products from China (Customs Value), U.S. International Trade Commission, 2020

⁶ Restoring America's Competitive Nuclear Energy Advantage: A strategy to assure U.S. National Security (Department of Energy, April 23, 2020).

American nuclear fuel cycle infrastructure, we are jeopardizing our defense capabilities and the contribution of nuclear technologies to our clean energy goals.

IV. THE STRATEGIC URANIUM RESERVE WILL PRESERVE THE URANIUM INDUSTRIAL BASE

The similarities of the challenges facing the uranium industry to our rare earth mineral dependence on China are startling. The NFWG determined that “America is on the brink of losing its ability to provide U.S.-origin nuclear fuel, threatening our national interest and national security.”⁷ But it is not too late to take control over our clean energy future.

American’s uranium producers are cost-competitive globally but for the price undercutting tactics of SOEs. Given a level global playing field, the domestic uranium industry has the capacity to produce significant quantities of cost-competitive uranium. According to the EIA, currently licensed/partially licensed operating and standby in situ recovery production capacity is about 22 million pounds of uranium concentrate production per year. Licensed conventional mill capacity equates to approximately 24 million pounds of uranium concentrate production per year. This annual capacity of 46 million pounds is almost the same amount of the average amount of uranium loaded into U.S. reactors from 2010-2019 (46.6 million pounds).⁸ There are also significant uranium resources for the future. The U.S. Geological Survey reports that the U.S. holds approximately 1.2 billion pounds known, reasonably assured, and inferred resources, and that it has more than three times that amount in prognosticated undiscovered resources.⁹

Uranium Resources of the United States



⁷ Restoring America’s Competitive Nuclear Energy Advantage: A strategy to assure U.S. National Security (Department of Energy, April 23, 2020).

⁸ EIA Uranium Marketing Annual Reports – Table 18

⁹ Critical Analysis of World Uranium Resources, U.S. Dept. of Interior, U.S. Geological Survey, Susan Hall and Margaret Coleman, 2012

With swift action to level the playing field for free market companies, we can take advantage of the licensed infrastructure, human resources, and production capacity we still have on standby by implementing the Strategic Uranium Reserve at the Department of Energy (DOE). Congress appropriated \$75 million for uranium purchases to fill the reserve on a bipartisan basis in the December 2020 omnibus appropriations bill. We urge DOE to move quickly to begin purchasing uranium this year, serving the three-part purpose of preserving the industrial base, creating a fuel reserve to guard against global supply disruptions, and creating a source of U.S.-origin uranium for future defense needs. We also urge Congress to grant the uranium reserve the full \$150 million in annual funding over the next ten years, as recommended by the NFWG report as well as DOE in its Fiscal Year 2021 budget request. \$150 million per year is a modest and sound investment considering it will procure a valuable, strategic asset for the federal government and preserve the nuclear fuel cycle in the U.S. instead of ceding it to Russia, China, and their allies.

V. CONCLUSION

In closing, I applaud the Committee for exploring ways to advance America's nuclear leadership and capabilities in support of clean energy goals, national security, and our global competitive presence. We look forward to working with the Committee to preserve today's nuclear infrastructure and supply chain, while also advancing a clean, reliable, and safe energy future for the U.S. in the form of advanced nuclear energy technologies.

The CHAIRMAN. Thank you, Mr. Melbye.

And next, we have Ms. Amy Roma, Founding Member of the Atlantic Council's Nuclear Energy and National Security Coalition and a Partner in the law firm, Hogan Lovells.

Ms. Roma.

STATEMENT OF AMY C. ROMA, FOUNDING MEMBER, NUCLEAR ENERGY AND NATIONAL SECURITY COALITION, ATLANTIC COUNCIL, AND PARTNER, HOGAN LOVELLS US LLP

Ms. ROMA. Good morning. My name is Amy Roma and I am a member of the Atlantic Council's Nuclear Energy and National Security Coalition and a lawyer at Hogan Lovells. Thank you for the opportunity to testify today.

Commercial nuclear power has always served as an important tool to achieve U.S. national security objectives and U.S. economic interests. In 1954, at the dawn of nuclear power, President Eisenhower delivered his famous "Atoms for Peace" speech, offering to share U.S. nuclear energy technology with other nations who committed not to develop nuclear weapons. This program resulted in three important economic and national security objectives. First, it prevented the spread of nuclear weapons. Second, it made the United States the leader in nuclear power, ensuring the U.S. maintained dominance in nuclear safety, security, innovation, and nuclear trade. And third, it ensured the U.S. benefited from the geopolitical relationship that goes with such significant assistance with a foreign country's power supply. President Eisenhower's historic move has paid dividends for decades, and the U.S. was long positioned as the global leader in commercial nuclear power and, remarkably, the same arguments used to support nuclear trade after World War II are still just as relevant today. That is that the United States should lead in nuclear trade because if we do not, another country will. And while the U.S. still has the largest nuclear fleet and best-run plants in the world, we have seen our international role as a global leader in nuclear power sharply decline, replaced largely by Russia, with China close behind.

Russia and China have identified building nuclear power plants and nuclear trade as national priorities promoted by the highest level of government and backed by state financing and state-owned enterprises. Their focus has paid off. Nuclear power plants are being built all around the world. But Russia is building them. Russia uses nuclear exports as a tool to exert foreign influence and reaps significant economic gains with a claimed \$133 billion in orders for foreign reactors. Nuclear energy is also a component of China's "Belt and Road" initiative, with China estimating it could have \$145 billion in orders for foreign reactors and create five million Chinese jobs. The U.S. nuclear power industry, competing against state governments for new projects, has quickly been sidelined on the foreign stage with no new orders for nuclear reactors abroad.

The global market opportunity is huge and growing and the impact of the lack of U.S. leadership is widely felt. The current market for new nuclear is already in the hundreds of billions of dollars. If carbon mitigation measures are deployed, the global nuclear market would be in the trillions of dollars. Sitting by the wayside

and letting Russia and China continue to capture this market hurts not only our country's economic interests, but also undermines U.S. national security, technical innovation, and geopolitical interest. Russian energy policy, in particular, expressly recognizes the export of energy technologies as a geostrategic tool to promote Russian national security. As one example, Egypt and Russia recently finalized a \$21 billion contract for the Russians to supply four reactors in Egypt. A few months later, Egypt and Russia announced a preliminary agreement to allow Russian military jets to use its air space and bases. This agreement will give Russia its deepest presence in Egypt since 1973.

While China appears to generally view nuclear power exports as an important economic opportunity, its expansion in developing new nuclear technologies also has defense implications. For example, China plans to build a number of floating nuclear reactors to provide power to the artificial islands that it is currently building in the South China Sea, a hotly contested area. These same weapons can support not only power for these islands, but also provide power for advanced weaponry.

While the U.S. has ceded the current mantle, we have a chance to regain it when it comes to the next generation of advanced reactors, where we hold a significant innovation edge. In particular, the U.S. leads the world in the development of advanced fission reactors as well as the nation's fusion industry. These advanced technologies are diverse, but share common design features, such as they are simple, scalable, and safe and can be used for both power and non-power applications such as hydrogen production, water desalinization, and process heat for industrial uses. U.S. innovation, when properly supported, can stand up to state-backed competitors. We saw this recently in the aerospace market. In 2013, Russia controlled about half of the launch industry. Due in large part to the success of SpaceX, shepherded by NASA's Commercial Orbital Transportation Services (COTS) program, Russia is now estimated to capture only ten percent of the market. We came back with a one-two punch. First, the punch of U.S. innovation, and second, the punch of the U.S. Government providing commercialization support.

So we can emerge here as a global leader in nuclear power with U.S. Government support. The opportunity is there. We have the innovation and the stakes are worth it. Thank you and I'm happy to answer any questions that you may have.

[The prepared statement of Ms. Roma follows:]

Written Testimony of Amy C. Roma

Founding Member, Nuclear Energy and National Security Coalition (NENSC), Atlantic Council; Partner, Hogan Lovells US LLP

Before the Senate Committee Energy and Natural Resources

Full Committee Hearing on The Latest Developments in the Nuclear Energy Sector with a Focus on Ways to Maintain and Expand the Use of Nuclear Energy in the United States and Abroad

Thursday, March 25, 2021, 10:00 a.m.

My name is Amy Roma and I am a founding member of the Nuclear Energy and National Security Coalition at the Atlantic Council and a nuclear regulatory lawyer at the law firm of Hogan Lovells. Thank you for the opportunity to testify before the Committee. This testimony represents my observations and in no way represents the views of the Atlantic Council, Hogan Lovells or its clients.

Commercial nuclear power has always served as an important tool to achieve U.S. national security objectives and U.S. economic interests. That holds just as true today as it did at the advent of the civilian nuclear power industry at the end of World War II. But nuclear power also affords additional key benefits, which have emerged more recently, making this technology even more important. First, nuclear power does not emit greenhouse gases, including carbon, and therefore can serve as a crucial tool in the battle against climate change, for both carbon-free power generation and decarbonization of other sectors such as industry and transportation. Second, nuclear power provides reliable power for generations. With the world electricity demand expected to double by 2050,¹ nuclear power has the ability to provide clean, affordable, and reliable power around the world, helping raise the global standard of living, including for the approximately 860 million people in the world with no access to electricity.²

I walk through these considerations below, first explaining the current state of affairs and how we got here, and then by walking through the opportunities to improve the U.S. position. There is a lot in here, that touches upon national security, global politics and policies, national politics and policies, economic opportunities and jobs creation, technological innovation—as it stands today and important areas where it will be going, and climate change. The facts are dense

¹ Energy Information Agency, *ELA projects nearly 50% increase in world energy usage by 2050, led by growth in Asia* (Sept. 24, 2019) (available at <https://www.eia.gov/todayinenergy/detail.php?id=41433>)

² TIME, *Bill Gates: Here's a Formula That Explains Where We Need to Invest in Climate Innovation* (Jan. 22, 2021) (available at <https://time.com/5930098/bill-gates-climate-change/>).

and the footnotes plenty, but there is an important story to tell and an important opportunity to seize.

I. A high stakes history lesson

Understanding the importance of commercial nuclear power begins with a history lesson that underscores the unique tool nuclear power can serve for the U.S. on the global stage.

Commercial nuclear power and the United States government share a long history that is intertwined with the global struggle for peace and security.³ Soon after the end of the Second World War, the U.S. government understood that its monopoly on nuclear weapons and nuclear technology would be short lived. In particular, the Soviet Union was catching up with the United States and could share the information with other countries to benefit its own geopolitical aims and undermine U.S. influence, safety, and nonproliferation policies.⁴

Facing the recognition that nuclear power would eventually become a global technology, in the 1950s President Eisenhower and his administration saw the value that sharing the peaceful use of nuclear power could bring not just for the world, but for its own security. President Eisenhower presented a bold proposal to the United Nations: The U.S. would share its nuclear energy technology with other nations if the receiving nation committed to not use the technology to develop nuclear weapons.⁵ This program, known as “Atoms for Peace,” furthered three important economic and national security objectives: (1) it prevented the spread of nuclear weapons because it would lead and thus have oversight over global nuclear development; (2) it made the U.S. the leader in nuclear power, ensuring that the U.S. maintained dominance in nuclear safety, security, nuclear technology development, and nuclear trade; and (3) it ensured the U.S. benefitted from the geopolitical relationship that goes with such significant assistance with a foreign country’s power supply.⁶

³ Michael Wallace, Amy Roma, and Sachin Desai, *Back from the Brink: A Threatened Nuclear Energy Industry Compromises National Security*, Center for Strategic and International Studies (Jul. 2018) (*available at* <https://www.csis.org/analysis/back-brink-threatened-nuclear-energy-industry-compromises-national-security>). Much of the content of this section of my remarks repeats and reemphasizes the points made in this paper.

⁴ Peter Lavoy, *Arms Control Today*, *The Enduring Effects of Atoms for Peace*, Arms Control Association (Dec. 1, 2003) (*available at* https://www.armscontrol.org/act/2003_12/Lavoy) (“U.S. officials feared that the Kremlin would score a huge propaganda victory, especially in the developing world, if the United States did not alter its own nuclear export policy.”)

⁵ Address of Dwight D. Eisenhower, President of the United States of America, to the 470th Plenary Meeting of the United Nations General Assembly (Dec. 8, 1953) (*available at* <https://www.iaea.org/about/history/atoms-for-peace-speech>).

⁶ It is worth reflecting that there are only nine countries today with nuclear weapons, despite President John F. Kennedy’s prediction that there would be as many as 25 nuclear-armed states by the 1970’s—this is in no small part due to these strong nonproliferation bulwarks put in place by the United States early in the development of nuclear power and the strong non-proliferation standards the U.S. continues to deploy today. Press Conference, President John F. Kennedy, President’s News Conference (Mar. 21, 1963) (*available at* <https://perma.cc/B7LW-7WYR>); Nuclear Weapons Programs Worldwide: An Historical Overview, INST. FOR SCI. & INT’L SECURITY (*available at* <https://perma.cc/3XQV-P7LY>).

President Eisenhower’s historic move has paid dividends for decades. With the United States at the forefront, the Atoms for Peace policy gave rise to many of the most important safety and nonproliferation standards of today’s nuclear world.

Remarkably, many of the same arguments used to support the U.S. government’s decision to bring nuclear power to the world in the 1950s are still just as relevant today—that is, the United States should lead in nuclear trade because if we do not, another country will, which undermines U.S. influence and economic interests, as well as U.S. safety and nonproliferation standards. However, under today’s current climate, Russia and China—and not the United States—dominate the global market. They have identified building nuclear power plants and nuclear trade as national priorities, and promote these priorities from the highest levels of government, backed by state financing and state-owned enterprises.

Their focus has paid off. Russia now dominates nuclear power plant construction around the world, using it as a tool to exert foreign influence and reap significant economic gains. Nuclear energy is also a component of China’s “Belt and Road” initiative, with China expected to exceed the U.S. as the largest domestic producer of nuclear power by 2030,⁷ and also emerge as a close competitor to Russia for international new nuclear projects.⁸ The struggling U.S. nuclear power industry—competing against foreign governments for new projects abroad—has quickly been sidelined on the foreign stage. *See* Appendix A for a global breakdown of Russian and Chinese nuclear exports.

While we have ceded the mantle currently, the United States has a chance to regain it when it comes to the next generation of advanced reactors, where we hold a significant innovation edge. In particular, the U.S. leads the world in the development of advanced fission reactors, as well as the nascent fusion industry.⁹ U.S. innovation, when properly supported, can stand up to state backed competitors. We saw this in the aerospace market. In 2013, Russia controlled about half of the launch industry.¹⁰ Due in large part to the success of SpaceX, shepherded by NASA’s Commercial Orbital Transportation Services (COTS) program, Russia is now estimated to capture only 10% of the market.

⁷ Nikkei Asia, *China poised to overtake US in nuclear power by 2030* (Aug. 31, 2020) (available at <https://asia.nikkei.com/Business/Energy/China-poised-to-overtake-US-in-nuclear-power-by-2030#:~:text=China%27s%20total%20nuclear%20power%20generation,Nuclear%20Association%2C%20an%20industry%20group>).

⁸ Reuters, *China could build 30 ‘Belt and Road’ nuclear reactors by 2030: official* (Jun. 20, 2019) (available at <https://www.reuters.com/article/us-china-nuclearpower/china-could-build-30-belt-and-road-nuclear-reactors-by-2030-official-idUSKCN1TL0HZ>).

⁹ *See* Fusion Industry Association website for an overview of fusion companies in the United States (available at <https://www.fusionindustryassociation.org/>). The U.S. Nuclear Regulatory Commission is currently evaluating the regulatory framework for fusion.

¹⁰ Ars Technica, *Russia appears to have surrendered to SpaceX in the global launch market* (Apr. 18, 2018) (available at <https://arstechnica.com/science/2018/04/russia-appears-to-have-surrendered-to-spacex-in-the-global-launch-market/>).

Likewise, if the United States leads in implementing this new technology wave with advanced reactors, we can regain leadership in the global nuclear industry, resulting in significant gains to U.S. interests.

II. The current state of the domestic nuclear industry

Nuclear boasts attractive features that routinely garner bipartisan support. It is on President Biden's radar as well as on the legislative agenda for both parties. The United States is currently the world's largest producer of nuclear power, accounting for more than 30% of worldwide nuclear generation. Nuclear energy provides approximately 20% of U.S. power generation and around 55% of the country's carbon-free power generation, with a fleet of about 95 reactors, operated by 30 different power companies across 30 different states.¹¹

The nuclear industry supports nearly half a million jobs in the United States and contributes about \$60 billion to the U.S. GDP annually.¹² Each nuclear power plant can employ up to 700 workers with salaries that are 30% higher than the local average, and they contribute billions of dollars annually to local economies through federal and state tax revenues.¹³ In addition to providing large amount of carbon-free power, it also operates incredibly well, providing reliable power with an average capacity factor¹⁴ of over 90% making it one of the most reliable power generation sources.¹⁵ Unlike many other forms of power generation, nuclear plants are also able to operate up to 60 and 80+ years, if they are licensed to do so, making nuclear power a reliable long-term investment. It is not surprising that nuclear power has been called "the safest, least polluting, least warming, and most reliable energy source humanity has yet devised."¹⁶

Despite these benefits, the current U.S. nuclear industry is facing a perilous decline. Almost all current U.S. nuclear generating capacity comes from reactors built between 1967 and 1990. As recently as 2013, the U.S. had 104 operating domestic nuclear power reactors, with dozens of new reactors planned in the early 2000s. But due in part to the long-term decline in natural gas prices beginning around 2008, the tide turned for the industry. Essentially all the new reactor projects were cancelled. Today the number of reactors has decreased to around 95 today with more scheduled for early decommissioning, and about 1/3 facing economic hardships.¹⁷ While two new plants are under construction, no other large scale units are planned after this time. And with

¹¹ World Nuclear Association, *Nuclear Power in the USA* (updated January 2021) (available at <https://www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.aspx>).

¹² U.S. Department of Energy, Office of Nuclear Energy, *Advantages and Challenges of Nuclear Energy* (Jan. 26, 2021) (available at https://www.energy.gov/ne/articles/advantages-and-challenges-nuclear-energy#:~:text=Creates%20Jobs,higher%20than%20the%20local%20average.)).

¹³ *Id.*

¹⁴ Capacity factor is the ratio between what a generation unit is capable of generating versus the unit's actual generation output over a period of time. Among other things, the higher the capacity factor, the more predictable the output of the plant.

¹⁵ Energy Information Agency, *Electric Power Monthly, Table 6.07.B. Capacity Factors for Utility Scale Generators Primarily Using Non-Fossil Fuels* (through Dec. 2020) (available at https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_b) (For comparison, wind has about a 35% capacity factor, and solar PV has about a 25% capacity factor).

¹⁶ Richard Rhodes, *Energy: A Human History*, Simon & Schuster, 1st edition (2018) at 336-37.

¹⁷ Energy Information Agency, *Frequently Asked Questions (FAQS)* (available at <https://www.eia.gov/tools/faqs/faq.php?id=207&t=3>).

roughly half of the nuclear fleet operating in “merchant” markets priced for the short term, the low price of natural gas is making nuclear plants temporarily uncompetitive. At the same time, however, certain critical benefits of nuclear power plants—e.g., reliability, grid stability, low-carbon energy source, national security asset—go largely uncompensated.

The loss of commercial nuclear power plants in the United States has also created and will continue to exacerbate a decline in the supporting infrastructure—especially in the front end fuel cycle supply chain (e.g., uranium mining, milling, conversion, enrichment, and fuel fabrication), human supply chain, and the military to civilian workforce pipeline—further jeopardizing not only our domestic ability to support our domestic fleet, but also our national security as that same infrastructure indirectly supports our nuclear maritime and other military capabilities. For example, despite having large uranium reserves, the United States has nuclear fuel production capacity that is not sufficient to meet our domestic needs and 95% of uranium used in U.S. commercial reactors is imported.¹⁸ Until recently, the U.S.’ only uranium conversion facility was shuttered, and while we do have an operating uranium enrichment facility in the United States, we do not currently have domestic enrichment capabilities to support the high-assay low enriched uranium (HALEU) fuel needs of our emerging advanced reactor companies.¹⁹

Despite these challenges, U.S. reliance on nuclear power has actually *grown*, with U.S. nuclear generation capacity doubling because of increased operational efficiencies and power plant utilization, and power uprates.²⁰ A number of states have moved to keep economically troubled nuclear power plants open to preserve their low carbon attributes, using a “Social Cost of Carbon” metric to support the cost-benefit analyses of the programs.²¹ But these state actions are all stop gap measures until a more permanent solution emerges. Unless new initiatives are shown, more nuclear power plants are expected to prematurely shutdown leading to a significant degradation of the existing commercial fleet.

¹⁸ World Nuclear Association, *U.S. Nuclear Fuel Cycle* (updated February 2021) (available at <https://www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-fuel-cycle.aspx>). To make clear, the United States has extensive domestic uranium resources, ranking ninth in the world for known uranium resources, with about 4 percent of the world total. At peak production, around 1980, there were over 250 uranium mines in operation, but there has been a steady decline in production since that time.

¹⁹ *Id.* See also Department of Energy’s Office of Nuclear Energy, *What is High-Assay Low-Enriched Uranium (HALEU)?* (Apr. 7, 2020) (available at <https://www.energy.gov/ne/articles/what-high-assay-low-enriched-uranium-haleu>). Most of the advanced reactor companies rely on HALEU, which is not commercially made in the United States. While the U.S. has some stockpiled, the stockpile is expected to run out of the next decade or so, which is also critical as the same stockpile is used to provide fuel for the U.S. naval propulsion program and power our nuclear navy. The U.S. Navy has approximately 100 nuclear reactors in its submarines and surface ships. See World Nuclear Association, *Nuclear-Powered Ships* (updated Feb. 2021), available at <https://www.world-nuclear.org/information-library/non-power-nuclear-applications/transport/nuclear-powered-ships.aspx>.

²⁰ Energy Information Agency, *Nuclear explained: U.S. nuclear industry* (last updated Apr. 15, 2020) (available at <https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php>).

²¹ For a summary of these program, please see HL New Nuclear Blog, *Biden Administration Reinvigorates the Social Cost of Greenhouse Gases*, by Amy Roma and Sachin Desai (Mar. 5, 2021) (available at <https://www.hlnewnuclear.com/2021/03/biden-administration-reinvigorates-the-social-cost-of-greenhouse-gases/>).

III. The current state of the global nuclear marketplace and the huge opportunity it affords

The nuclear community is expanding across all corners of the globe. There are currently around 440 reactors in operation around the world, with about 50 reactors under construction in 16 countries.²² There are also a number of advanced reactor technologies under development—about 130 in total—using cutting-edge technologies and capabilities (*see* Appendix B).²³ And this is just the beginning as nuclear power is increasingly seen as a critical tool in combatting climate change and electrifying the underserved populations of the world with clean, reliable, and affordable energy.

According to projections from Third Way and the Energy for Growth Hub, the market for nuclear could triple by 2050 and generate \$400 billion of electricity annually.²⁴ The Department of Commerce has identified that over the next ten years, the international market for nuclear equipment and services will yield about \$740 billion, and every \$1 billion of exports by U.S. companies could support anywhere from 5,000 to 10,000 jobs domestically.²⁵ If carbon mitigation measures are deployed, the 30-year cumulative market domestic opportunity for nuclear power could reach up to \$2 trillion, within a global market valued at around \$8.6 trillion.²⁶ But even without any carbon mitigation measures, the current market for new nuclear power is in the hundreds of billions of dollars. There are very big numbers that present a very big opportunity for the United States.

With prospects such as these on the horizon, if the U.S. expects to become competitive, it must align its policies and programs with that goal.²⁷ This is what the competition is doing. While globally, nuclear power is taking off, the U.S. has been struggling to gain a foothold in the foreign market competing against the aggressive tactics of Russia and China. These countries have invested heavily into building power plants across the world, starting with traditional large light water reactor technology offerings. Low-cost “turnkey” projects offered by the Russians and Chinese—which include state-supported financing packages, and “build, own, operate” models that handles the entire project and fuel cycle from start to finish—shuts out the United States. Nuclear development in these countries is government-backed, including financial, political and regulatory support, making it almost impossible for the U.S. to compete globally. *See* Appendix A.

²² World Nuclear, *Plans for New Reactors Worldwide* (Mar. 2021) (available at <https://www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx>).

²³ Third Way, *2020 Advanced Nuclear Map: Progress Amidst a Tumultuous Year* (Dec. 21, 2020) (available at <https://www.thirdway.org/graphic/2020-advanced-nuclear-map-progress-amidst-a-tumultuous-year>).

²⁴ Third Way, *Mapping the Global Market for Advanced Nuclear* (Sept. 22, 2020) (available at <https://www.thirdway.org/memo/mapping-the-global-market-for-advanced-nuclear>).

²⁵ Nuclear Energy Institute, *Nuclear Exports & Trade Overview* (available at <https://www.nei.org/advocacy/compete-globally>).

²⁶ *Global Nuclear Market Assessment Based on IPCC Global Warming of 1.5° C Report*, Prepared by UxC, LLC for the Nuclear Energy Institute (Jul. 2020), at 1 and 4 (available at <https://www.nei.org/resources/reports-briefs/uxc-global-nuclear-market-assessment-report>).

²⁷ Breakthrough Energy, *Advancing the Landscape of Clean Energy Innovation* (Feb. 2019) (available at <https://www.breakthroughenergy.org/reports/advancing-the-landscape/>).

Russia dominates the global nuclear new build marketplace, and has secured 60% of nuclear reactor sales around the world.²⁸ Russia has more than 50 reactors either under construction, planned, or proposed in 19 countries.²⁹ Russia has stated that its book of business for nuclear construction projects is well over \$130 billion,³⁰ and it further estimates that every 1 ruble of nuclear export contributes 2 rubles to national GDP. Russia has also developed the first modern floating small modular reactor technology, and is paving the way for fast reactors with closed nuclear fuel cycles through its Proryv Project where fuel is recycled to reduce nuclear waste.

China is coming up close on its heels.³¹ China has built almost half of all nuclear reactors constructed since 2000 and has designed numerous others outside its borders.³² China further estimates that it could build as many of 30 overseas reactors by 2030 (which is just 20% of the anticipated “Belt and Road” market), earning up to \$145.5 billion and employing up to 5 million Chinese workers.³³ China has 49 operable nuclear reactors domestically and 16 currently under construction.³⁴ Aligned with its goal of becoming a leader in nuclear, China is exploring advanced nuclear options as well as maintaining and developing its nuclear fleet. As noted above, China is building a molten salt reactor for potential application on aircraft carriers for naval population and flying drones.³⁵ China also recently closed its bidding process that solicited interest for a 152-meter, 33,069-ton nuclear-powered vessel.³⁶

These government investments are not wasteful but strategic, because Russia and China realize the economic and geopolitical benefits of having their customers dependent on Russian and Chinese-managed energy resources, and keeps Russia and China on top of technical innovations that can advance their own interests.

Russian energy policy, in particular, expressly recognizes the export of energy technologies as a geostrategic tool to promote Russian national security. While China appears to generally view nuclear power exports as an important economic opportunity, its expansion into developing new

²⁸ Nuclear Energy Institute, *Russia and China Are Expanding Nuclear Energy Exports. Can the U.S. Keep Up?* (Oct. 6, 2020) (available at nei.org/news/2020/russia-china-expanding-nuclear-exports-us-keep-up). World Nuclear Association, *Plans for New Reactors Worldwide* (updated Jan. 2021) (available at <https://www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx>.)

²⁹ World Nuclear Association, *Nuclear Power in Russia* (updated Jan. 2021) (available at <https://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx>.)

³⁰ *Id.*

³¹ World Nuclear Association, *Plans for New Reactors Worldwide* (updated Jan. 2021) (available at <https://www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx>.)

³² VOA News, *China on Track to Supplant US as Top Nuclear Energy Purveyor* (Jan. 14, 2020) (available at <https://www.voanews.com/east-asia-pacific/voa-news-china/china-track-supplant-us-top-nuclear-energy-purveyor>).

³³ *Xi Touts BRI Nuclear Energy*, Analysis: In the News, Center for Strategic and International Studies (Aug. 2, 2019), <https://reconnectingasia.csis.org/analysis/entries/bri-goes-nuclear/>.

³⁴ World Nuclear, *Nuclear Power in China* (Jan. 2021) (available at <https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx>).

³⁵ Michael Wallace, Amy Roma, and Sachin Desai, *Back from the Brink: A Threatened Nuclear Energy Industry Compromises National Security*, Center for Strategic and International Studies (Jul. 2018) (available at <https://www.csis.org/analysis/back-brink-threatened-nuclear-energy-industry-compromises-national-security>).

³⁶ South China Morning Post, *Could China's 'experimental' ship be the world's biggest nuclear-powered icebreaker?* (available at <https://www.scmp.com/news/china/military/article/3002455/china-build-30000-tonne-nuclear-powered-ship-described>).

nuclear technologies also has defense implications. For example, China plans to build a number of floating nuclear reactors to provide power to the artificial islands that it is building in the South China Sea, a hotly contested area.³⁷ Also important to note, these reactors can support not only power for these islands but provide power for advanced weaponry.

As China and Russia succeed in the deployment of their nuclear energy technologies in emerging economies, they gain critical geopolitical influence in these countries by effectively controlling baseload power and the fuel cycle to run these nuclear units. This influence runs for the long-term, at least for the life of the project and plant which can stretch to 100 years, with long-term implications for the geopolitical balance of power and economic influence.

For example, Egypt and Russia recently finalized a \$21 billion contract for the Russians to supply four reactors in Egypt.³⁸ A few months later, Egypt and Russia announced a preliminary agreement to allow Russian military jets to use its airspace and bases. The agreement will give Russia its deepest presence in Egypt since 1973.³⁹

But there is opportunity still to turn things around as the world energy demand sky rockets and the decarbonization intensifies. Around 30 countries across the Middle East, Africa, Central and South America, Europe, and Southeast Asia are considering or beginning new nuclear power programs—each of which is an opportunity for the U.S. to regain a foothold in the global market.⁴⁰ In Europe, Hungary and Poland are planning to site new nuclear reactors to replace retired energy systems.⁴¹ A United Kingdom government whitepaper sets forth the Prime Minister’s plan to tackle climate change and includes both large and small scale nuclear.⁴²

Simply put, the global market is huge and the opportunities to promote U.S. economic and national security interests are immense.

³⁷ See *China's Risky Plan for Floating Nuclear Power Plants In The South China Sea*, *The Diplomat*, by Viet Phuong Nguyen (May 10, 2018) (available at <https://thediplomat.com/2018/05/chinas-risky-plan-for-floating-nuclear-power-plants-in-the-south-china-sea/>).

³⁸ See Al-Masry Al-Youm, *Construction of First Nuclear Reactor at Dabaa Station to Start after Christmas Holidays*, *Egypt Independent* (Dec. 13, 2017) (available at <http://www.egyptindependent.com/construction-first-nuclear-reactor-dabaa-station-start-christmas-holidays/>). The article notes that of the \$21 billion price tag for the four new reactors, Russia will fund 85 percent of the plant through a loan, and the rest will be financed by Egypt. The deal was finalized in September 2017.

³⁹ See David D. Kirkpatrick, *In Snub to U.S., Russia and Egypt Move toward Deal on Air Bases*, *New York Times* (Nov. 30, 2017) (available at <https://www.nytimes.com/2017/11/30/world/middleeast/russia-egypt-air-bases.html>). (“The United States has provided Egypt more than \$70 billion in aid in the four decades since, at a rate of more than \$1.3 billion a year in recent years. The cost is often justified in part by the argument that it secures the use of Egypt’s airspace and bases for the U.S. military.”)

⁴⁰ World Nuclear, *Emerging Nuclear Energy Countries* (Mar. 2021), (available at <https://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx>).

⁴¹ World Nuclear News, *Hungary and Poland plan nuclear to replace coal* (Mar. 5, 2021) (available at <https://www.world-nuclear-news.org/Articles/Hungary-and-Poland-plan-nuclear-to-replace-coal>).

⁴² HM Government, *Powering our Net Zero Future* (Dec. 2020) (available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_B_EIS_EWP_Command_Paper_Accessible.pdf).

IV. Turning things around and leading with advanced reactors

In the near term, advanced reactors are the only planned new nuclear endeavors to add to the nuclear energy mix in the United States this decade, but they are also well poised to give the U.S. an opportunity to regain its global nuclear leadership.

There are about several dozen domestic ventures in next-generation nuclear technologies and new opportunities are being created every day—including two leaders in this field that are also providing testimony today (*see* Appendix B, for a global perspective of advanced nuclear development, showing significant activity in the United States).⁴³ These endeavors take many forms and have a variety of technical features. Indeed, there are also a number of fusion ventures looking to demonstrate and commercialize fusion power technologies.

Critically, however, nearly all contain enhanced safety systems, such as passive safety features and below grade construction. Moreover, nearly all of them offer modular designs that can start small and scale with customer needs. In addition, many advanced reactors have the ability to provide process heat, which can be used to decarbonize the industrial sector and support other innovative technologies, such as hydrogen production or water desalination, and even space propulsion/power and shipping, as discussed more below.⁴⁴

Over the past decade advanced reactor designs have significantly matured, and many vendors are hoping to build their first plant this decade. On October 13, 2020, the U.S. Department of Energy awarded X-energy and TerraPower \$80M each for their respective initiatives to build advanced nuclear reactors by 2027 under the Advanced Reactor Demonstration Program (ARDP). ARDP facilitates a 50-50 cost-sharing partnership with the nuclear industry to ensure that advanced nuclear technology is rapidly demonstrated. Several other advanced reactor company also received ARDP awards for their projects and are in discussions with the U.S. Nuclear Regulatory Commission (NRC) for licensing.⁴⁵ Another company, Oklo, has a combined construction permit and operating license application under review with the NRC, and NuScale recently received NRC approval of its design and is in discussions with Utah Associated Municipal

⁴³ Third Way, *Mapping the Global Market for Advanced Nuclear* (Sept. 22, 2020) (available at <https://www.thirdway.org/memo/mapping-the-global-market-for-advanced-nuclear>). Third Way has been tracking advanced reactor develops for several years now and their data shows an increased tick in participants each year. *See, e.g.,* Third Way, *Keeping Up with the Advanced Nuclear Industry* (Jan. 2018) (available at <https://www.thirdway.org/graphic/keeping-up-with-the-advanced-nuclear-industry>). This number shows a marked increase from the previous year, so the advanced reactor field is currently growing. *See also* Third Way, *The Advanced Nuclear Industry: 2016 Update* (Dec. 12, 2016) (available at <https://www.thirdway.org/infographic/the-advanced-nuclear-industry-2016-update>).

⁴⁴ *See, e.g.,* World Nuclear Association, *Nuclear Process Heat for Industry* (updated September 2020) (available at <https://www.world-nuclear.org/information-library/non-power-nuclear-applications/industry/nuclear-process-heat-for-industry.aspx>) and *Nuclear Reactors and Radioisotopes for Space* (updated February 2021) (available at <https://www.world-nuclear.org/information-library/non-power-nuclear-applications/transport/nuclear-reactors-for-space.aspx>).

⁴⁵ *See* Department of Energy's Office of Nuclear Energy, *Energy Department's Advanced Reactor Demonstration Program Awards \$20 million for Advanced Reactor Concepts* (Dec. 22, 2020) (available at <https://www.energy.gov/ne/articles/energy-department-s-advanced-reactor-demonstration-program-awards-20-million-advanced>).

Power Systems to site NuScale reactors at Idaho National Laboratory.⁴⁶ The Department of Defense is also working with U.S. companies to design a micro-reactor to deploy at forward operating bases to provide reliable power in war zones and eliminate fuel delivery-related deaths.⁴⁷

If given a chance to thrive through private sector investment, regulatory streamlining, and political leadership on issues such as management of spent fuel, nuclear power could see an incredible resurgence in the United States, bringing significant benefits to its citizens, national security, and even prospects in space.

Listed below is just a brief selection of some of the benefits advanced reactors can provide the U.S. economy if adequately supported:

- **High-Paying Jobs:** Investment in nuclear power will result in skilled, highly compensated jobs in the nuclear industry, including the addition of professions such as reactor designers and service and maintenance professionals, as well as opportunities in fuel cycle facilities to mine, mill, and enrich uranium. These positions open the door for highly skilled domestic employees, many of whom come to the field from the Navy or after pursuing extensive university programs.⁴⁸ In fact, today nuclear power has the highest paying jobs in the entire electric power generation sector, with the average mid-wage workers earning somewhere between 22% and 25% more per hour than the next best paying electric power generation sector (e.g., coal and natural gas, respectively) and about 30% more than average local wages.⁴⁹
- **Low-Carbon Power:** Advanced reactors are an important component to a diverse clean-energy fields. Advanced reactors can produce more energy than alternative renewable

⁴⁶ World Nuclear News, *NuScale and UAMPS agreements progress plans for SMR plant* (Jan. 12, 2021) (available at <https://world-nuclear-news.org/Articles/NuScale-and-UAMPS-agreements-progress-plans-for-SM>).

⁴⁷ See *U.S. Military's mobile mini-nuclear: fewer fuel supply convoys mean fewer casualties*, Energy Post, by James Conca (May 17, 2019) (available at <https://energypost.eu/u-s-militarys-mobile-mini-nuclear-fewer-fuel-supply-convoys-mean-fewer-casualties/>) ("Multiple studies identify that air and ground delivery of liquid fuel comes at a significant cost in terms of lives and dollars. Approximately 18,700 casualties, or 52% of the approximately 36,000 total U.S. casualties over a nine-year period during Operation Iraqi Freedom and Operation Enduring Freedom occurred from hostile attacks during land transport missions, mainly associated with resupplying fuel and water." See also Army Environmental Policy Institute, *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys Final Technical Report* (Sept. 2009) (available at <https://apps.dtic.mil/dtic/tr/fulltext/u2/b356341.pdf>).

⁴⁸ See, e.g., Department of Energy, *Nuclear Energy University Program* (available at <https://www.energy.gov/ne/nuclear-reactor-technologies/nuclear-energy-university-program>). Since 2009, the Nuclear Energy University Program has awarded "approximately \$290 million to 89 colleges and universities in 35 states and the District of Columbia to train the next generation of nuclear engineers and scientists in the United States and continue U.S. leadership in clean energy innovation."

⁴⁹ See Energy Futures Initiative and the National Association of State Energy Officials, *U.S. Energy and Employment Report*, at 108, 113 and 119 (2020) (available at <https://www.usenergyjobs.org/>); American Nuclear Society, *The U.S. Nuclear R&D Imperative: A Report of the American Nuclear Society Task Force on Public Investment in Nuclear Research and Development*, at 13 (Feb. 2021) (available at <https://www.ans.org/file/3177/2/ANS%20RnD%20Task%20Force%20Report.pdf>); U.S. Department of Energy, Office of Nuclear Energy, *Advantages and Challenges of Nuclear Energy* (Jan. 26, 2021) (available at <https://www.energy.gov/ne/articles/advantages-and-challenges-nuclear-energy#:~:text=Creates%20Jobs,higher%20than%20the%20local%20average>).

sources over less land. And while renewable energy sources like solar and wind will play an important role in our clean energy framework, nuclear energy provides a unique, efficient and reliable solution. As previously noted, a recent report estimates that based on future carbon mitigation goals, the U.S. nuclear market revenues could amount \$2 trillion over the next 30 years, and the global market could reach over \$8 trillion.⁵⁰ But even just looking at today's market, we know new nuclear projects are already resulting in hundreds of billions of dollars in global market opportunities. This growth and development is further spurred by the current focus, both domestically and abroad, on combatting climate change.

- **Reliable, Low-Carbon Process Heat:** Nuclear energy may be the only reliable zero-carbon source of industrial process heat in desalination, oil refining, ethanol production, and the like. The industrial sector contributes around 28% of global greenhouse gas emissions and its decarbonization will cost anywhere between \$11 trillion and \$21 trillion.⁵¹ Using nuclear in place of current energy alternatives in process heat applications can result in price stability, no carbon emissions, and increased security.⁵² Besides its proven value in industrial processes, nuclear can also be used to create power generation sources, like hydrogen, for decarbonization. For example, heat from high-temperature nuclear reactors can potentially provide energy necessary for electrolysis, which can be used to make hydrogen production more efficient.⁵³ Future high-temperature reactors may also be used to make hydrogen thermochemically.⁵⁴
- **U.S. Leadership and R&D:** Investing in the nuclear innovation also adds value to the U.S. research mission by providing engineers and scientists resources for research, supporting our National Laboratories, universities, and staying on top of technology innovation.⁵⁵ The research resulting from nuclear reactors at leading U.S. universities and the National Laboratories has numerous spin-offs for other disciplines, such as superconductors, polymers, metals, and proteins.⁵⁶ Nuclear technology also aids in determining quality control for aerospace, automotive, and medical components.

⁵⁰ UxC, LLC, *Global Nuclear Market Assessment Based on IPCC Global Warming of 1.5° C Report* (Jul. 2020) (available at [https://www.nci.org/CorporateSite/media/filefolder/resources/reports-and-briefs/UxC-NEI-\(IPCC-2050-Nuclear-Market-Analysis-PUBLIC\)-2020-07-01.pdf](https://www.nci.org/CorporateSite/media/filefolder/resources/reports-and-briefs/UxC-NEI-(IPCC-2050-Nuclear-Market-Analysis-PUBLIC)-2020-07-01.pdf)).

⁵¹ McKinsey, *Decarbonization of industrial sectors: the next frontier* (Jun. 2018) (available at <https://www.mckinsey.com/business-functions/sustainability/our-insights/how-industry-can-move-toward-a-low-carbon-future>).

⁵² World Nuclear Association, *Nuclear Process Heat for Energy* (Sept. 2020) (available at <https://www.world-nuclear.org/information-library/non-power-nuclear-applications/industry/nuclear-process-heat-for-industry.aspx>).

⁵³ *Id.*

⁵⁴ World Nuclear Association, *Hydrogen production and uses* (Feb. 2021) (available at <https://www.world-nuclear.org/information-library/energy-and-the-environment/hydrogen-production-and-uses.aspx>).

⁵⁵ U.S. Nuclear Regulatory Commission, *Background on Research and Test Reactors* (last updated May 5, 2020) (available at www.nrc.gov/reading-rm/doc-collections/fact-sheets/research-reactors-bg.html).

⁵⁶ *Id.*

- **Safety and Non-Proliferation Leadership** Promoting U.S. nuclear technology globally will also help ensure high standards for safety and nonproliferation continue in place to the benefit of our children.⁵⁷ The U.S. has lead in setting the safety and security standards that have made nuclear power so safe around the world. We have an incredibly robust regulator, the U.S. Nuclear Regulatory Commission, that serves as a global “Gold Standard” for nuclear regulators around the world and which helps advise other countries on regulatory oversight. The U.S. exports its strict nuclear governance standards and governance culture—including the critically important Nuclear Safety Culture—when it works abroad, helping to ensure plants are run safe. When countries work with the U.S., they agree to strict commitments on the sharing of nuclear technology (i.e., U.S. 123 Agreements); adopt U.S. operational safety standards (e.g., those promulgated by the U.S. Institute of Nuclear Power Operations, which are further re-enforced with the World Association of Nuclear Operators standards); and set forth a global fuel supply framework that reduces risk of proliferation.
- **U.S. National Security**: The U.S. Navy has a command of the sea that affords the United States unrivaled international influence, due to the nuclear reactors powering its aircraft carriers and submarines. For decades, the size and sophistication of ships nuclear reactors can support have enabled leaders in Washington to project American power over much of the earth, during times of both war and peace.⁵⁸ New reactor designs that are likely to move naval vessels faster and more efficiently. Indeed, China is building a molten salt reactor (a new type of advanced nuclear reactor) for potential application on aircraft carriers for naval population and flying drones.⁵⁹ Beyond the high seas, as discussed above advanced reactors can deploy at forward operating bases to provide reliable power in war zones or distant locations, and eliminate fuel delivery-related deaths.
- **Leadership in Space**: Nuclear power itself is a key component of extra-orbital space research. For example, the Voyager spacecraft⁶⁰ and the Mars rover, Curiosity, use Radioisotope Thermoelectric Generators (RTGs) to continue to function.⁶¹ According to a recent report by the National Academies of Sciences, Engineering, and Medicine, both nuclear thermal propulsion (NTP) and nuclear electric propulsion (NEP) systems “show great potential” in the realm of space exploration, particularly in a human exploration of

⁵⁷ Atlantic Council, *U.S. Nuclear Energy Leadership: Innovation and the Strategic Global Challenge*, Report of the Atlantic Council Task Force on U.S. Nuclear Energy Leadership (May 2019) (available at https://www.atlanticcouncil.org/wp-content/uploads/2019/05/US_Nuclear_Energy_Leadership-.pdf); see World Nuclear Association, *Nuclear Power in Russia* (last updated July 2020) (available at <https://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx>).

⁵⁸ See Council on Foreign Relations, *Sea Power: The U.S. Navy and Foreign Policy*, by Jonathan Masters (Aug. 19, 2019) (available at <https://www.cfr.org/backgrounder/sea-power-us-navy-and-foreign-policy>).

⁵⁹ Michael Wallace, Amy Roma, and Sachin Desai, *Back from the Brink: A Threatened Nuclear Energy Industry Compromises National Security*, Center for Strategic and International Studies (Jul. 2018) (available at <https://www.csis.org/analysis/back-brink-threatened-nuclear-energy-industry-compromises-national-security>).

⁶⁰ NASA, *Voyager Spacecraft* (available at www.voyager.jpl.nasa.gov/mission/spacecraft/).

⁶¹ NASA, *Radioisotope Power Systems* (available at www.rps.nasa.gov/).

Mars, although NASA and DOE must prioritize the development of such a mission if it is expected to come to fruition.⁶²

V. Path Forward

This is a pivotal time for the U.S. energy innovation and the failure to recognize the case for advancing nuclear development with full-force Congressional support will be a major loss for this country. Innovative U.S. companies working hard on advanced nuclear technologies should not be tempted to develop their work abroad for a lack of support at home. Americans who have dedicated their careers to supporting the energy sector should not miss out on well-paying jobs because the U.S. could not recognize a major opportunity in a growing field in time. And global safety and security should not be compromised due to the U.S.'s inaction in leveraging its relationships with other countries for the common good. Supporting the existing nuclear fleet and providing the resources and backing necessary for advanced nuclear to thrive can help keep the U.S. as a forerunner in the nuclear industry globally.

With this incredible expanse of nuclear globally, U.S. innovation in nuclear power can stand up to state backed competitors. As discussed above, we saw this in the aerospace market when Russia ceded control of the global commercial launch industry due to the 1-2 punch of U.S. innovation (led by SpaceX) and U.S. government commercialization support (demonstrated through the NASA COTS program).⁶³

There are many ways Congress can help support this industry, including by continuing to fund and support the Department of Energy's ADRP program, other R&D initiatives, moving forward on spent fuel disposal solutions, supporting the existing fleet and infrastructure, supporting efforts to streamline and improve the efficiency of NRC licensing and exports, supporting efforts to expand financing options for new nuclear projects, including through the Export/Import bank and Development Finance Corporation, just to name a few.

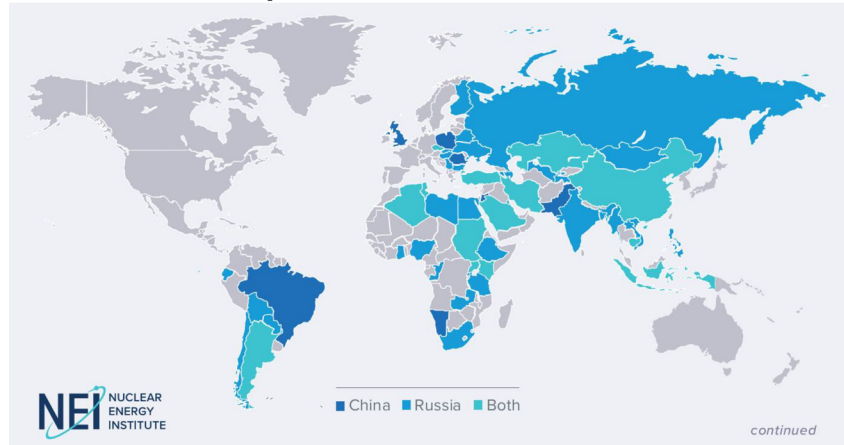
Thank you for the opportunity to testify before this Committee on the importance of nuclear power in our current and future energy structure.

⁶² National Academies of Sciences, Engineering, and Medicine, *Nuclear Propulsion for Human Mars Exploration* (2021) (available at <https://www.nationalacademies.org/our-work/space-nuclear-propulsion-technologies>).

⁶³ Ars Technica, Russia appears to have surrendered to SpaceX in the global launch market (Apr. 18, 2018) (available at <https://arstechnica.com/science/2018/04/russia-appears-to-have-surrendered-to-spacex-in-the-global-launch-market/>).

Appendix A

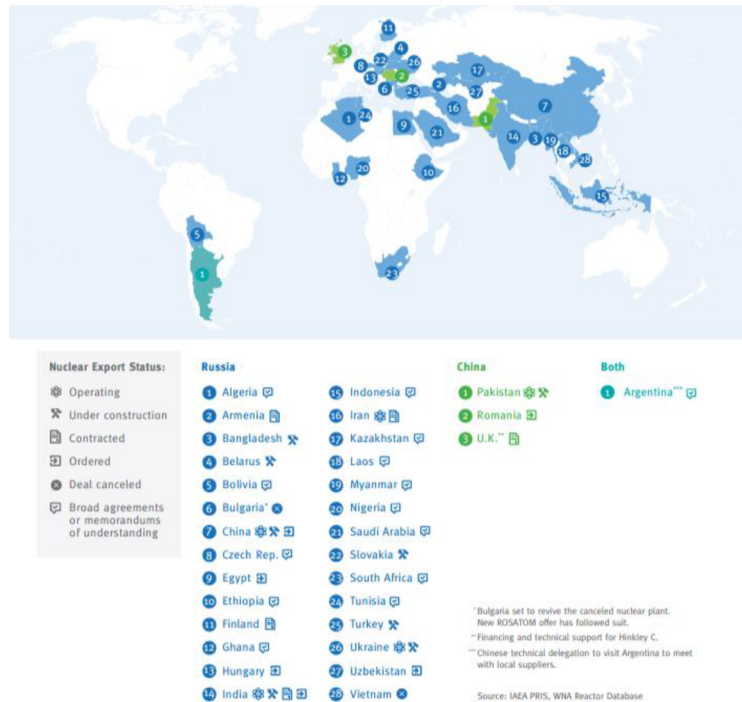
Map 1. Russia and China Global Presence



Source: Nuclear Energy Institute, 2020⁶⁴

⁶⁴ Nuclear Energy Institute, *Russia and China Are Expanding Nuclear Energy Exports. Can the U.S. Keep Up?* (Oct. 6, 2020) (available at nei.org/news/2020/russia-china-expanding-nuclear-exports-us-keep-up).

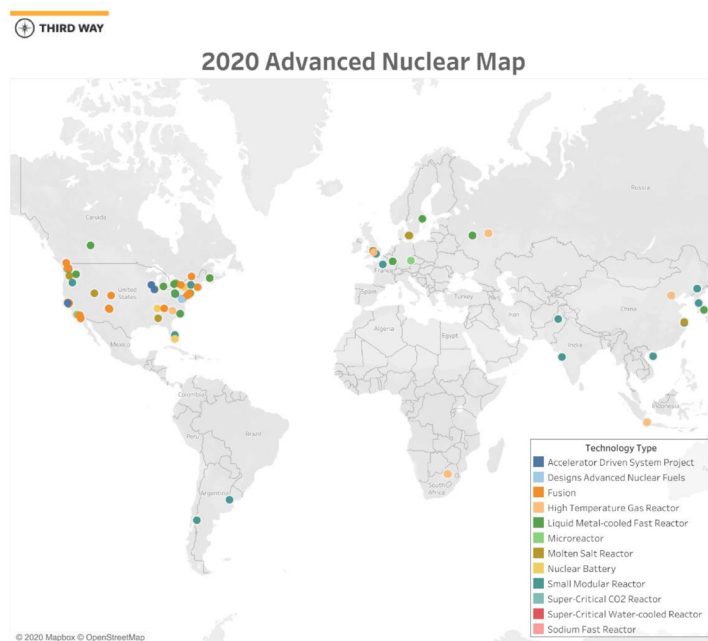
Map 2. Russian and Chinese LWR Export Targets



Source: Global Nexus Initiative, 2019⁶⁵

⁶⁵ Global Nexus Initiative, *Responding to Climate Change and Strengthening Global Security* (2019) (available at <https://globalnexusinitiative.org/results/reports/advancing-nuclear-innovation-responding-to-climate-change-and-strengthening-global-security/>).

Attachment B
Map 1. Global Advanced Nuclear Technology Development



Source: Third Way, 2020.⁶⁶

⁶⁶ Third Way, *2020 Advanced Nuclear Map: Progress Amidst a Tumultuous Year* (Dec. 21, 2020) (available at <https://www.thirdway.org/graphic/2020-advanced-nuclear-map-progress-amidst-a-tumultuous-year>).

The CHAIRMAN. Thank you, Ms. Roma.
 And now we have Mr. Sell. He is our final presenter and he is CEO of X-energy.
 Mr. Sell.

**STATEMENT OF J. CLAY SELL,
 CHIEF EXECUTIVE OFFICER, X-ENERGY**

Mr. SELL. Chairman Manchin, Ranking Member Barrasso, and members of the Committee, thank you again for the opportunity to provide testimony today on current developments in the U.S. nuclear energy sector. I respectfully request that my full written testimony be submitted for the record and I will briefly summarize my remarks.

The CHAIRMAN. Without objection.

Mr. SELL. My name, again, is Clay Sell and I'm the Chief Executive of X-energy, a clean energy technology company founded by Dr. Kam Ghaffarian. We are developing Generation IV, high-temperature, gas-cooled, nuclear reactors and we are also a manufacturer of special TRISO-X fuel used in our reactors and other advanced reactors emerging on the market. Our commercial plant has four 80-megawatt electric modules and totals 320 megawatt electric. It's in an optimized configuration sharing a single control center and other plant infrastructure. Our plant is intrinsically safe, benefits from a simplified and flexible design, and is economically attractive for a variety of electricity and process heat applications. This is the plant that we will build with our utility partner, Energy Northwest, as part of the Advanced Reactor Demonstration Program, authorized by this Committee and signed into law last year. Our DOE award will deliver a project requiring approximately \$2.5 billion in expenditures between now and 2027 to achieve three major scopes of work. We will complete the final design and licensing of the plant at the U.S. NRC. We will license and construct the first phase of our commercial fuel plant in this program, and we will construct, fuel, and commission the commercial-scale plant in Richland, Washington.

I came back to the nuclear industry with X-energy two years ago after ten years in the oil and gas and renewable development business. I do have a passion for nuclear energy and I've had it for 20-plus years, but that is not the reason I came back to nuclear energy. I came back because of the immensity of the business opportunity before us. With global energy demand increasing by 50 percent by 2050 and the need to dramatically reduce carbon emissions, the business opportunity for nuclear power is simply massive. And we at X-energy see a different future for nuclear power than what has gone on before and we are creating it with the help of visionary leaders in the Congress and the Department of Energy. I believe the revitalization of the U.S. nuclear industry is a strategic imperative for our country.

Now, as I testify along Mr. Levesque from TerraPower—they are the other U.S. company that was awarded a demonstration contract. I just want to make something clear—TerraPower, as a company, is a respected competitor and a company that we hold in the highest regard. But they are not the real competition. The real competition, as you've heard in other testimony today, is state-

owned, Chinese and Russian companies. And today, those companies have replaced the United States as the dominant sellers of new nuclear power plants in the world. The Chinese and Russian enterprises know that nuclear power plant sales in foreign markets create 80- to 100-year relationships that become tightly woven into the fabric and destiny of a country's energy and critical industrial infrastructure. If the U.S. will not, or if the U.S. cannot compete in these export markets, the resulting global realignment of nuclear commerce will negatively impact our national security interests and our international influence for decades to come. In this geopolitical light, the Advanced Reactor Demonstration Program takes on even greater importance and value. I know that Congress recognizes this and sees the ARDP as a necessary and powerful tool that will reinvigorate our domestic and export industries, including uranium production and domestic enrichment capabilities, thereby allowing the U.S. to reclaim its position of global leadership and influence now.

I would like to highlight three challenges that require continued vigilance. First, availability of sufficient quantities of high-assay low-enriched uranium, known as HALEU, to fuel both the X-energy and TerraPower reactors. We will need that beginning in 2024 and it remains a critical concern. The Committee has provided strong leadership, but I have outlined additional policies in my written testimony that I respectfully urge the Committee to pursue. Second, continued reform and evolution of the NRC licensing framework, appropriate to the reduced risk and improved safety cases of advanced reactors, will require continued vigilance. And finally, predictable and consistent appropriations to match the billions of dollars of private capital committed to these demonstrations will be essential to delivering the projects on schedule by 2027.

I hope I have provided you some insight into the value of this program and the exciting market opportunities. At X-energy, we are proud to join with the leadership of the Committee to reclaim our global leadership position in this great American-born industry to create thousands of new, high-paying American jobs, to enhance our energy and national security, and to ensure the high standards for safety and security around the world.

Thank you for the opportunity to testify. I look forward to your questions.

[The prepared statement of Mr. Sell follows:]

Testimony of J. Clay Sell, Chief Executive Officer

X-energy

Senate Energy and Natural Resources Committee

March 25, 2021

Good Morning Chairman Manchin, Ranking Member Barrasso, and Members of the Committee.

I am Clay Sell, CEO of X-energy, one of the leading companies to help the U.S. develop a next generation of advanced nuclear reactors, which we believe, is one of the cornerstones of our nation's efforts to develop reliable carbon-free energy at scale to help fuel a growing global economy. Advanced nuclear reactors build upon a decade of technology development and risk reduction that enable them to be safer and far less prone to proliferation. They are the cutting edge of America's efforts to be innovative in the energy sector. If allowed to reach their potential, with the help of this Committee and its partners in the Congress and the Administration, advanced reactors can usher in a new era of cleaner energy, and high paying U.S. jobs, allow us to reduce our carbon footprint and compete globally for new energy infrastructure projects.

The Opportunity: A little background on me. Twelve years ago, I left the Department of Energy and Washington, DC to build the renewables energy portfolio company at Hunt Consolidated/Hunt Oil Company. I came back to the nuclear industry two years ago to work for X-energy. I have a passion for nuclear energy—I have for 20 years. But that is not why I came back. I came back to nuclear energy because of the immensity of the business opportunity before us. It is simply massive. And we at X-energy see a different future for nuclear power than what has gone on before, and we are creating it with the help of visionary leaders in the Congress and the Executive branch. Advanced nuclear technologies like our Xe-100 system have reached a level of technical readiness to be able, by the second half of this decade, to provide a significant contribution to U.S. energy independence and clean energy for our allies around the globe. To achieve any of the proposed policy objectives with respect to greenhouse gasses and, including to be net carbon zero by 2050, the U.S. alone will need to generate more than 1,100 to 3000 gigawatts of new power, and globally, that number jumps probably by a factor of five, as the US consumes about 17% of all world energy today. In fact, based on outside market analysis for SMRs, the Total Addressable Market to 2050 is 170 gigawatts of electricity—not including China. That is an incredible business opportunity. In addition, advanced reactors can contribute to non-electric uses such as heating and industrial processes and can be a significant source in the production of hydrogen. Another significant feature of advanced reactors is their ability to load follow. This means they can serve as an attractive base

load power in combination with intermittent renewables because they are able to adjust their power output as demand for electricity fluctuates throughout the day.

These combined factors point to a transformed energy future for America and our planet, while reviving our energy manufacturing supply chain and creating good paying jobs. The continued support of our industry by the Congress and the Administration is critical so we can actually build and operation these future plants. As you can tell I am passionate about making this happen. You have my commitment that I will do everything that I can to ensure that X-energy meets its schedule, budget and deployment plans as we embark on the Advanced Reactor Demonstration Program.

I believe the revitalization of the U.S. nuclear industry is a strategic imperative for our country. As I sit here with Mr. Levesque from Terrapower, the other U.S. company to recently be awarded a demonstration project under ARDP, let me make clear, Terrapower is not the competition – it is the Chinese and the Russians. They have replaced the United States as the dominant nuclear energy powers on the world stage. Let me spend a couple of minutes on the opportunities in the global new nuclear energy marketplace. The next potential market opportunity we see is in Canada. The Canadians have set aggressive clean energy goals and have very clearly articulated the critical role of nuclear power in meeting those goals. They are very intent on deploying advanced nuclear energy technology and their schedule is only a year or so behind the United States. While Canada will clearly choose Western technology, as we look to other countries around the world, the competitive landscape is more wide open.

As noted by the Atlantic Council, The World Nuclear Association has identified thirty countries as emerging markets for nuclear energy technologies, and most of the countries in question are not members of the OECD. The regions focused on acquiring civil nuclear capabilities include: Eastern Europe; the Middle East and North Africa; Western, Central, and Southern Africa; Central and South America; and East and Southeast Asia". Make no mistake, the Chinese and the Russians, through their State-controlled businesses and as part of their stated diplomatic goals, are very much engaged in marketing their nuclear reactors to all these regions. As a nation, we need to recognize, as have the Chinese and the Russians, that nuclear power relationships are 80-100 year relationships that become tightly woven into the fabric and destiny of a country's energy and industrial critical infrastructure. If we do not, or cannot participate at the same level as our adversaries in that development, the tremendous global realignment potential that will likely result, will negatively impact our national security interests and international influence. While exporting nuclear technology can be challenging, the implications of not being able to compete in the global market now will be felt most significantly in the long term. However, to compete – we will have to have deployed our reactors domestically. Almost no other country will buy a first-of-a-kind reactor.

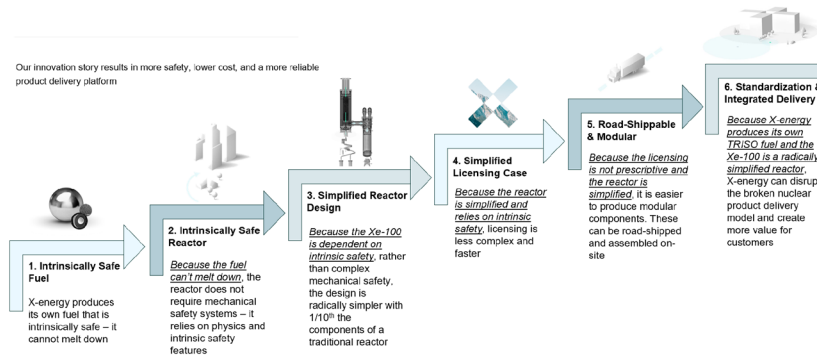
In this geopolitical light, the Advanced Reactor Demonstration program takes on even greater importance and value. I do believe the Congress has recognized this, and does see the ARDP as a necessary and powerful tool in developing the overall nuclear energy landscape, which also

includes international financing, uranium production and domestic enrichment capabilities, and a licensing framework that aligns appropriately with the risks of advanced reactors.

The Technology: X-energy was founded 12 years ago by Kam Ghaffarian our Executive Chairman and lead investor. The choice of a High Temperature Gas-Cooled pebble-bed Reactor (HTGR) was based in large part on the maturity of the technology and the previous investments that the U.S government has made in this technology – both on the reactor side, and the fuel qualification side. We have been able to take what has been done in the past – in Germany, the United States, and South Africa -- learn from those operating reactors and experiences in the 1970's and 1980's, and design the reactor and plant in a way that offers a safe, modular, and affordable approach to deployment.

The heart of the safety case for HTGR reactors is the graphite and ceramic encased fuel: TRI-structural ISOTropic particle fuel, or "TRISO fuel". The Department of Energy has hailed TRISO fuel as "the most robust nuclear fuel on Earth." Five years ago, when X-energy won its first cooperative agreement with DOE, we decided that we needed to make our own fuel so that we could meet the schedule, quality and the quantity of fuel that we would need for our reactors and was a pivotal part of our business case. This decision was made building on over \$350M of Federal investment in TRISO fuel manufacturing, characterization, irradiation, and post radiation evaluations, as well as licensing qualification activities that have been conducted by DOE's Oak Ridge National Lab (ORNL) and Idaho National Lab (INL). It is precisely this government investment that gave us the confidence to transition what had been done in the labs to commercial scale. Using our initial 5-year funding of \$53M (\$40M from the Department of Energy and \$13M X-energy cost-share) we built a TRISO pilot-scale manufacturing facility at ORNL that we have been running since 2016. We chose to build not a lab, but a commercial scale facility, utilizing what would represent one line of fabrication equipment. We view this as a critical part of the fuel facility licensing process. Indeed, we have been producing particles and pebbles, analyzing them, and comparing them to the specimen utilized in the various Advanced Gas Reactor campaigns. We have also been allocated a small amount of high assay low enriched uranium "HALEU" which will allow us to begin irradiation on our particles in their final form later this year.

So, how are we using this HTGR and TRISO heritage? We started with a design approach that is focused on safety and its ability to be licensed by the Nuclear Regulatory Commission. We separated the nuclear island from the conventional island to enable us to utilize as many non-customized systems as possible, and we are making the plant affordable to the market. We accomplish this in what we call our "Ladder of Innovation":



As you can see, HTGR technology is not new, but we are designing it in innovative ways so it will be cost effective to customers, lowering the chance of increased costs to consumers and other rate payers, while enabling vastly improved safety, more agile construction and efficient operations.

Our HTGR reactor technology -together with TRISO-X fuel - is the linch-pin of the company. With innovative approaches we have recently been able to grow in related areas. So today we are actually in four business areas:

- **Xe-100:** Our commercial, grid-scale High Temperature Gas-Cooled reactor that will be first deployed through the Advanced Reactor Demonstration Program and then globally
- **TRISO-X Fuel:** All our reactors use tri-structural isotropic (TRISO) particle fuel, developed and improved over 60 years. We manufacture our own proprietary version (TRISO-X) to ensure supply and quality control.
- **Xe Mobile Reactor:** To address the need for ground, sea and air transportable small power production. We've developed reactor concepts with potential military and civilian government, remote community and critical infrastructure applications.
- **Space Nuclear Applications:** We have been supporting NASA, DOE, and DOD in applying our technology and fuel for nuclear thermal propulsion and fission power for the lunar surface

The Advanced Reactor Demonstration Program: First, I would like to commend the leadership of this Committee and the Congress for creating of the Advanced Reactor Demonstration Program and making sure it is funded annually in DOE's appropriations bill. The Nuclear Energy Leadership Act (NELA) coalesced various initiatives needed by the advanced reactor community

into an overall policy. ARDP is a remarkably bold policy initiative designed to restore U.S. leadership by demonstrating advanced reactor designs that will allow the U.S. industry to begin the process of reclaiming its position of global leadership and influence in the 2025-2027 timeframe.

X-energy understands the stakes, has developed its own market entry plans, and has signed our cooperative agreement with the U.S. Department of Energy (DOE) to deliver the first-ever commercial-grid-scale advanced reactor to the market by 2027. The construct of this program, while extremely challenging, is really the key needed to achieve deployment. The ARDP program is not like a conventional government procurement. We must deliver an advanced reactor at a commercial grid-size whose First-of-a-Kind system will attract additional customers and enable the U.S. to be the world leader in producing these advanced reactors. Government funds must be matched with non-Federal capital on a dollar-for-dollar basis – a 50%-50% costshare. We must have a customer/utility that is willing to participate from the time of selection. Finally, we must have a business plan that shows real potential for multiple sales beyond the first reactor and which will enable us to have multiple customers. We strongly believe our team will deliver on this!

X-energy has partnered with Energy Northwest for our ARDP deployment. Energy Northwest is a consortium of 27 public utility districts and municipalities across Washington state that provide power to 1.5 million public customers. Energy Northwest operates numerous sources of power generators. However, in 2019, Governor Inslee signed into law the Clean Energy Transformation Act, which requires Washington state to be 100% clean energy by 2045. This was a key driver in Energy Northwest evaluating their options and in choosing to be a leader in potential advanced reactor deployment. The partnership of X-energy and Energy Northwest proposed the demonstration of a four unit 320 MWe Nuclear Power Plant (NPP) to be owned and operated by Energy Northwest as NRC licensee. We will locate the plant on Energy Northwest's existing Washington Nuclear Project #1 (WNP-1) site, which is on a portion of the land it has leased on the Hanford Reservation near Energy Northwest's Columbia Generating Station.

Our ARDP goal is to demonstrate that our flagship reactor, the Xe-100, can be affordably built to compete with other energy sources to provide electricity to Energy Northwest's public utility customers. Our ARDP Project will accomplish two objectives:

1. Construct and perform commercial-scale operations of a nuclear power plant based a "four-pack" of our Xe-100 reactor at Energy Northwest's WNP-1 site within 7 years.
2. Construct a commercial-scale TRISO Fuel Fabrication Facility (FFF) with sufficient supporting infrastructure and transportation capabilities to initially support our four-pack plant, with growth capacity to support multiple plants, various reactor concepts, and terrestrial and space applications. This is an extension of X-energy's working commercial-scale equipment and processes for kernel, TRISO particle, and compact fabrication at our TRISO-X Pilot Facility at Oak

Ridge National Lab (ORNL). The facility equipment and stations are state-of-the-art, commercial-scale, and criticality safe.

The Challenges: There is no doubt that this is an ambitious program. However, given the high level of private investment, and the high level of risk reduction which X-energy has done over the last dozen years, we believe it a public private partnership that will achieve the critical objectives DOE has set out for the program. That does not mean there are not challenges. I would like to highlight the three challenges that we believe will drive the success of this program and determine whether or not this sector of the energy industry will grow to meet the challenges we face over the next three decades:

1. Availability of High Assay Low-Enriched Uranium (HALEU) in time to ensure that the fuel we need can be fabricated to meet our reactor schedule.
2. Assurance that the NRC meets the schedule it has set out for licensing review and approval.
3. Appropriated funds from the Government that recognizes of the funding profiles associated with construction of our reactor and associated elements and demonstrates that the government is a reliable partner, as we seek matching capital.

HALEU: Our biggest concern is the availability of High Assay Low Enriched Uranium (HALEU) to meet the first core load of the reactors, and then to have it available to meet other customer needs. Current reactors run on uranium fuel that is enriched up to 5% with uranium-235. Many advanced reactors, including those that utilize TRISO fuels, require uranium enriched between 5% and 20%. This is due to our smaller designs that get more power per unit of volume. HALEU will also allow developers to optimize their systems for longer life cores, increased efficiencies and better fuel utilization. Unfortunately, there are no domestic commercial providers of HALEU available today.

The Congress recognized this issue of the front end of the fuel cycle in the Consolidated Appropriations Act for FY21 by including \$75 million as a down payment to create a uranium stockpile/reserve. In addition, section 2001 of the Energy Policy Act, included as part of Division Z of the Consolidated Appropriations Act, sets forth elements to develop a demonstration effort to achieve a domestically produced source of advanced nuclear fuel. While we appreciate greatly this step towards a domestic HALEU capability, section 2001 would not require any consortium that emerges from this program to make HALEU available for commercial advanced reactors until 2026. This would significantly jeopardize our schedule to deliver under the ARDP by as much as two years. **Moreover, we also believe that the DOE should create a strategic HALEU reserve, and such a stockpile could then lead to the creation of a viable U.S. market under which multiple domestic providers of TRISO fuel would emerge.** So, there is actually a short-term challenge that specifically addresses the needs of the early demonstration reactors that must be met under schedule constraints, and there is a longer

term challenge which is to develop a domestic enrichment capability that will meet the market needs in 2026 and beyond. The near-term path might be an extension or complement of the uranium stockpile provision that includes the government procuring enough HALEU to meet the timetable and amounts needed for the next 10 years. Then the utilities or reactor companies can buy HALEU from the government when they need it. Without a timely source of HALEU, the breakthrough in advanced reactors on which we are on the verge of achieving will be at great risk.

NRC Licensing: The next few years represent a nexus of significant regulatory activities that will consume the collective attention and resources of the industry, NRC staff, and other stakeholders: rolling out and implementing near-term guidance for advanced reactor licensing applications, rulemakings on emergency planning and security, efforts to streamline environmental reviews, an extremely important effort to develop the transformational regulatory framework of Part 53, and multiple advanced reactor designs coming into the NRC for various review activities. Make no mistake: advanced reactors like the Xe-100 undergoing licensing as part of ARDP must address the licensing risks and uncertainty associated with draft review guidance, limited precedents, and a lot of historical bias – as in, “This is the way we’ve always done it”, - in order for us to demonstrate our business case and deploy on schedule.

This also represents some of our greatest opportunities. We have risk-informed, performance-based activities like the Licensing Modernization Project guidance to help applicants and the NRC staff focus on the most important elements of the reactor's safety design approach. We also have the opportunity to use ARDP as a vehicle to demonstrate, through trial use and pilot activities, new approaches that will transition us from an existing prescriptive, often inflexible regulatory framework towards a set of regulations that are truly technology-inclusive, risk-informed, and performance-based. A transformational regulatory framework is vital to deploying advanced reactors more broadly in the late 2020's and 2030's in a predictable, efficient, cost-effective, and timely manner.

USG funding stability – ARDP is indeed a public private partnership which we all believe will lead to a thriving advanced nuclear industry. The structure of the program requires us to raise over \$1billion of private capital for the first-of-a kind nuclear plant. I would like to stress that this is unprecedented in the history of nuclear reactors. At X-energy, we have taken on this challenge and we will be successful. The demonstrations are very large projects and basically follow a bell-shaped spending profile: design is completed, the licensing process gets underway, long lead systems and subsystems are ordered and built, the fuel facility is built and fuel manufacturing begins, and at the plant site environmental assessments are done, and preparation and construction begins. To meet the timetable of 2027, there are many of these activities that will occur in parallel rather than sequentially. While we proposed this project knowing that it would be subject to annual appropriations, I would like to impress on this Committee the criticality of the government investment being funded to match the necessary spend profile. We are often asked about the government's support of this project by potential

investors, and the implied risk of that funding uncertainty to impact schedule and cost. We need funding certainty for such a large, complex, and lengthy project. We know you will be watching us carefully and taking note of us meeting our progress and milestones. I can only ask, then, that you consider full funding of this demonstration program to ensure that with both sides meeting its commitments, we will see a successfully operating reactor in 2027! In the event that the Congress considers an extraordinary infrastructure package this year that includes investment in Clean Energy, we think it imperative that serious discussion should occur to fund both a strategic HALEU reserve and supplementary funds to accelerate investment in the ARDP. Both are critical for the nation to achieve a viable clean energy future and we believe that is a horizon in which American companies and their technology should be the world leader.

The Success: I hope I have provided you some insight into the value of ARDP to X-energy and the excitement of new market opportunities. We do seriously consider it our window of opportunity to demonstrate that advanced reactors can be built affordably, deliver what we say we can deliver, and will spark an excitement that will propel the nuclear industry to new heights for decades to come.

At X-energy we are proud to join with the outstanding leadership of this Committee in executing upon the policies that will allow the U.S. to *reclaim* its global leadership position in this great American born industry, for our own energy and national security, and to ensure the highest standards for safety for our world.

The CHAIRMAN. I want to thank all of you experts for your presentations. We appreciate it very much.

I am going to turn it over now to Senator Barrasso. I have to go to a quick meeting. I will be right back. He will start with the questioning and we will continue with questions.

Senator Barrasso.

Senator BARRASSO. Thank you, Mr. Chairman.

Mr. Melbye, could you please explain why it is so important that the United States maintain our ability to produce and process our own uranium?

Mr. MELBYE. Well, Senator Barrasso, uranium, as you know, is a critical mineral in every sense of the definition, not only supplying 20 percent of our electricity in the United States, it is over half of our carbon-free energy, and the use in The Nuclear Navy and other defense programs cannot be understated where we definitely have to have the domestic infrastructure available to support those programs. It's also about nuclear leadership around the world as well, as we're going to be competitive against China and Russia in competing in markets for these advanced reactors, including small modular reactors. We need to have the whole package, and fuel cycle is part of that. It's something our competitors—our government competitors are offering. We need to be competitive in that as well.

Senator BARRASSO. So last year Congress appropriated \$75 million to establish the Strategic Uranium Reserve through the Department of Energy. Why is it so urgent that the Department establish that reserve, begin a pre-purchasing program, and buy American-produced uranium this year?

Mr. MELBYE. Well, Senator Barrasso, as you know, the uranium market conditions have really been crushed by, I would call it, predatory pricing by these state-owned entities, but we still have the infrastructure in place. We still have the companies and expertise hanging on to recover and grow and not just survive, but thrive in the uranium industry, but we do need that support, urgently. We've gone through quite a period of low uranium prices, but the promise of the uranium reserve has already resulted in significant serious measures being taken at a number of our member companies to advance their operations, to be ready to supply into that uranium reserve very quickly.

Senator BARRASSO. Thank you.

Mr. Levesque, I appreciate you joining us from the other side of the country and I appreciate the work that you have been doing. In your testimony, you discuss how TerraPower's Natrium advanced nuclear reactor is safer to operate, produces lower volumes of waste, and is cheaper to build than conventional light-water reactors. You also discuss how the Natrium reactor will power a molten salt energy storage system, which can store much more energy than a typical battery storage facility could do.

Could you elaborate on the benefits of the Natrium reactor?

Mr. LEVESQUE. Yes, Senator, I would be happy to.

You know, and I should begin by referencing the great safe operating record of light-water reactors that are operated by TVA, for example, that Mr. Lyash discussed. I have, in fact, operated light-water reactors earlier in my career as a submarine officer. Those

reactors are very safe and TerraPower totally agrees that light-water reactors, like the ones at TVA, should have license extensions to 60, 80 years, possibly more.

So beginning with that great safety record, there are, in fact, technologies that have been developed in the national labs for literally decades, and by companies like TerraPower and X-energy, that are now ready for demonstration. To focus on TerraPower's Sodium technology, as I mentioned, Sodium is a sodium-cooled reactor. So where past reactor designs—the ones that have been demonstrated by the U.S. in the late '50s at the Shippingport Station, for example—past reactor designs are water-cooled, high-pressure systems. Sodium is a low-pressure system that operates hundreds of degrees Centigrade from the boiling point of the coolant, which is sodium. That offers great safety benefits. Also, sodium naturally retains radioactive materials like iodine and cesium so you don't have to worry about those radioactive isotopes getting out into the containment and into the environment. So it offers an order-of-magnitude lower accident and severity rate on an already great record in the light-water reactors today. Also, the fact that it's a low-pressure system is really important for reducing cost. Light-water reactors today are high-pressure systems that not only need very heavy components, but need heavy piping systems and heavy civil structures, heavy buildings and steel to support them. If you start with a lower pressure system, your components can then be lighter and your civil structures can then be lighter and cheaper as well.

TerraPower also has a really novel architecture. Instead of boiling water with our reactor heat directly—the way reactors have done for over 50 years—we looked really closely at what's going on with the grids today and the growing expansion of wind and solar, which is good for clean energy and good for decarbonization. But that's creating grid resiliency issues and energy storage needs. So with Sodium, what we're doing with the heat, before we boil the water to run turbines the conventional way, we first store the heat in large molten salt storage tanks—the same technology that concentrated solar plants have today because they have to deal with the sun going in and out—but their customer demand is there all the time. So what Sodium does on top of having these safety and cost benefits, it's really the first American nuclear reactor—first nuclear reactor anywhere—that offers energy storage. And instead of being a baseload supply of electricity, as nuclear has been for 50 years, Sodium now provides a peaking capability that can ramp up and down as intermittent sources like wind and solar come and go.

Senator BARRASSO [presiding]. Thanks so very much.

Senator Cantwell.

Senator CANTWELL. Thank you, Mr. Chairman and thank you to you and Senator Manchin for holding this important hearing. Obviously, the State of Washington has had a long history in nuclear power and I think that continues today. We are here to talk about the impacts of the next generation of nuclear energy. And I would say that the workforce in the Tri-Cities is especially excited about that. They have had a long history there, today over 12,000 nuclear-skilled scientists, engineers, and craft workers are working

there in 100 different companies. So it certainly is a home to a lot. Columbia Basin and Washington State University campuses offer bachelor's, master's and Ph.D.s in nuclear-related fields, and the region hosts a strong apprentice program. In fact, I would like to enter, if I could, Mr. Chairman, into the record, a letter from Nick Bumpaous, President of 16 affiliated unions of Central Washington, in support of DOE's Advanced Reactor Demonstration Program.

Senator BARRASSO. Without objection, so ordered.

Senator CANTWELL. Thank you.

[Letter from Nick Bumpaous, President of CWB&CTC follows:]

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March 23rd, 2021

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

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

Dear Chair Manchin and Ranking Member Barrasso,

I write this letter today on behalf of the 16 Affiliated Unions of the Central Washington Building and Construction Trades Council (CWB&CTC) regarding the recent Advanced Reactor Demonstration Program (ARDP) awards and subsequent project announcements in Richland, Washington.

The proud men and women of the Central Washington Building Trades have long cherished and maintained a deep sense of obligation and responsibility to meeting our State and Nation's most important economic and security goals. Through our own deep investments in trade apprenticeships, industry advancement, training and continuing education, our members have continued to provide the support, skill and professionalism needed to ensure every sector of our economy such as, aerospace, Cold War cleanup/remediation, cloud storage and energy generation continue to remain competitive, innovative and thriving.

It is our opinion that the recent DOE ARDP investment will not only serve as a catalyst for the further creation of family wage careers and apprenticeship opportunities in our region but will assist in progressing our Nation's priority of cultivating new manufacturing opportunities and the critical supply chain infrastructure needed to ensure America's global leadership in the energy technologies of the future.

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Additionally, the CWB&CTC believes that our region is uniquely positioned to assist and even lead these efforts as a technical and practical hub for research, development and innovation in the solutions that will ensure the United States can meet future challenges.

Central Washington is host to a multitude of resources we believe to be integral to overall success, such as, the Pacific Northwest National Labs, Washington State University with it's associated nuclear programs, available transmission infrastructure, geographic resources and a technical workforce that provides a synergy of expertise with a regional commitment to progress, ensuring favorable conditions optimal for success.

Our members and their families applaud the leadership of the United States and believe that conquering the challenges associated with mitigating climate change and providing affordable clean energy for future generation is achievable. We stand ready to serve and look forward to supporting the future of energy technology and infrastructure in our region and the Nation.

Respectfully,



Nickolas A. Bumpaous
President

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Senator CANTWELL. Obviously, PNNL [Pacific Northwest National Laboratory] gets a lot of money, \$400 million, I think, a year to do R&D in nuclear-related fields. So we are very excited overall about this next generation of clean power.

Mr. Sell and Mr. Levesque, you both testified to the benefits, particularly in comparison to light-water reactors, but how integral is the federal support for the advanced nuclear energy technology as a continuation to meeting our goals? And how important is Washington State's Clean Energy Transformation Act, you know, requiring sources be carbon-free by 2030, as a motivation to keep going? Also, I wanted to, you know, I should just mention, I certainly appreciate Bill Gates' and Nathan Myhrvold's efforts on TerraPower over a long period of time and recognition that the company is there.

And Mr. Sell, you and I just had a conversation about X-energy's larger footprint in the Tri-Cities, so anyway, we're all good. So maybe just tell the rest of us about the state's initiative and the federal support and what we need to keep doing.

Mr. SELL. The first thing I will say is the federal support through the Advanced Reactor Demonstration Program is critical to seeing first-of-a-kind reactors built.

Senator CANTWELL. You mean commercialization?

Mr. SELL. Yes, I mean, we are demonstrating a full-scale commercial plant, just like the plant that we will sell in Canada, that we hope to sell to TVA, that we hope to sell around the world. But the first plant is always the most challenging one to get built because all of the inherent risks associated with the first-of-a-kind plant. And so the federal support, in our case, is putting \$1.2 billion into the project, but the private sector is matching that with \$1.2 billion. So it's a critical accelerator to investment.

We wanted to be in Washington State for our first-of-a-kind project. We wanted to partner with Energy Northwest. We have great regard for their CEO, Brad Sawatzke, and the way he has dramatically improved the operations of their single nuclear reactor over the last ten years. But the critical thing was the way the market has been shaped by the Clean Energy Transformation Act in Washington, that was passed in 2019. That is the most transformative thing that has happened in nuclear energy markets in the United States because it has created the commercial framework for nuclear to succeed and to succeed wildly. And as Washington State phases out coal by 2027 and then natural gas by 2045, that's going to generate an eight-gigawatt gap of baseload, emissions-free power that needs to be filled. And the opportunity to do that with nuclear power, to continue the great nuclear tradition in Washington State, to continue the great tradition of emissions-free generation, is something that we really look forward to doing in Washington State by 2027 and we anticipate that we'll break ground on the initial non-nuclear construction there by the middle of 2023.

Senator CANTWELL. Mr. Levesque, hard to top that, but you can try.

Mr. LEVESQUE. Yes, nice to see you again, Senator Cantwell, and thanks for all your support in Washington. TerraPower is based in Bellevue, Washington, near Seattle. I completely agree with Mr.

Sell's points on the kind of federal and state support that has really been positive in the last couple of years. I'll elaborate a little bit on the design of the Advanced Reactor Demonstration Program. It's really an excellent program for many reasons. I think the chief reason being the public and private cost share.

These technologies that we're talking about, Generation IV advanced nuclear technologies, they've been worked on in the national labs for up to 20 years. TerraPower is a 14-year-old company. We have been working on the Sodium design with private investment, funding work at national labs, but all that work is really for naught if we don't demonstrate the reactor. These will just be power points and technical papers if we don't demonstrate the new technology, the way the U.S. did in the late 1950s. We demonstrated light-water technology at the Shippingport Station in Pennsylvania, which led to 400 reactors around the world based on U.S.-origin technology. If we don't demonstrate now, all of this technology investment that's been made by companies like TerraPower, X-energy, and government investment at the national labs, it will be for naught.

So the ARDP is coming at the perfect time. You heard about the growing demand for electricity that's going to come with electrification of transportation and the industrial sectors. Well, at the same time, we're shutting off coal. That's going to create a great demand for clean energy generation like TerraPower's Sodium reactor. So the ARDP is really well-designed in that it requires significant private cost share. If we think about the investment that TerraPower will be making during the construction of the demonstration reactor, you know, that investment and X-energy's will certainly be the largest private investments in nuclear energy in history, and the ARDP enabled this.

Senator CANTWELL. Thank you.

Mr. LEVESQUE. Now, why is—yes?

Senator CANTWELL. Thank you. I am sorry. I am way over my time.

Mr. LEVESQUE. Okay.

Senator CANTWELL. I appreciate your fine points. I am going to ask, Mr. Chairman, a question for the record that we can get the witness on because it begs the question, if what Washington did in setting this market or in encouraging this kind of development, obviously again, in coordination with the Federal Government, what else could we be doing on setting a more predictable price that would signal to the rest of the United States and otherwise stop reactors from being shut down?

So I do think it is an interesting question. We will get the witnesses on that, but thank you, Mr. Chairman, for this important hearing.

Senator BARRASSO. Thank you very much.

Senator Cortez Masto.

Senator CORTEZ MASTO. Thank you. Thank you so much. I appreciate the hearing today. Let me just say to the Chairman very quickly because, as everybody knows—I am from Nevada. I am for consent-based siting for nuclear waste. I think it is something that needs to be done and I think, particularly, as we look to nuclear

power this is an issue we have to address as a country. And I think every state should be treated equally.

So let me just thank the Chairman for his opening remarks. I also want to just recognize, again, that S. 541, the Nuclear Waste Informed Consent Act, that Senator Rosen and I introduced, I think is so important. I hope that my colleagues, we can all, along with the industry, address this issue, but treat every state equally, every state should be part of the solution and be treated equally.

So I appreciate the opportunity just to make that statement.

Mr. Melbye, let me start with you. In your written testimony, you raise some concerns about our domestic workforce, noting that the nuclear industry, and I quote, "requires trained, experienced, and skilled engineers, geologists, scientists, technicians, and operators." I am curious to hear more about the current overall status of our workforce and whether or not the panel thinks that the U.S. has enough nuclear engineering professionals to fully ramp up development and deployment of advanced nuclear technologies.

Mr. MELBYE. Well, thank you, Senator, and I can speak from the experience of our company, Uranium Energy Corp. You know, as I sit around our operational staff meetings and I look around at the folks around the table, a lot of them are in their 60s and even into their 70s and providing consulting, even after they leave our company. We've tried, as a company, to really provide mentoring for younger people and professionals and we've been able to do that, but it's difficult in a low uranium price environment to have that kind of bench strength, but I'm totally confident that schools like Texas A&M, Colorado School of Mines, and the University of Wyoming are ready to take on those next generation. The knowledge transfer hasn't been lost yet. So if we ramp up when we can and I know on the reactor side, our university and laboratory programs around the country are putting out young people that are very eager to get into small modular and advanced reactors as a way to really advance their interests in science and technology and do something to improve the planet through cleaner energy technologies.

So I think we have a young next generation of willing employees, both in the fuel cycle, but also in reactor development.

Senator CORTEZ MASTO. Okay.

And I want to hear from the rest of the panel. I only have so much time, so I—this is an issue that is important for, I think, for all of us to understand and make sure we are investing in our workforce, as well, as we move forward. But there is one thing I want to touch on and it goes back to my concerns about the nuclear waste, and this is for the panel members.

How do—or how should—advanced nuclear reactor technologies compare to current in-use technology when it comes to the production of nuclear waste? Can you address that and can we talk a little bit about that and the difference between, and how we would address, the nuclear waste situation we are in?

Mr. SELL. Senator—

Mr. LEVESQUE. Go ahead, Clay.

Mr. SELL. Thank you, Chris.

Senator, my name is Clay Sell, with X-energy, and our waste profile is a material improvement over the light-water waste situa-

tion in four chief respects. Number one, we're a much more efficient user of uranium and so, from an efficiency standpoint, we produce less waste per megawatt generated. Number two, our fuel form is a ceramic-encased material and it is a tremendous fuel form, but it is an even better waste form. And so, when you think about this waste being stored in a geologic repository, you don't have to consider the kinds of degradation that you face with metal-clad fuels.

The third thing is we never have to cool this waste in water. It's just air-cooled, and our plant has the ability to store all of the waste that we will produce in the 60-year life of the plant onsite. So we're confident that with your legislation and other similar efforts, that a consent-based system will lead to a nuclear waste solution, a geologic repository, at some point in the next 60 years, but we have got the issue covered in a safe, responsible way that will be fully appreciated by our stakeholders and we do not anticipate that as a significant issue holding up the advanced reactors.

Thank you.

Senator CORTEZ MASTO. Thank you. Thank you.

And I know my time is up. I will submit the rest of my questions for the record. Thank you so much.

The CHAIRMAN [presiding]. Next, we have Senator Hickenlooper.

Senator HICKENLOOPER. Great. Thank you all for your excellent testimony and I want to kind of take up where Senator Cortez Masto left off. Just to come back to that, you know, one of the great challenges of developing new nuclear energy assets beyond the cost is the fear, and that there is still this residual concern and fear about, you know, is this new facility going to be built in my community and what are those risks? And can advanced nuclear technologies offer a solution to this and in that process, how do we address some of those issues of fear?

Mr. LYASH. Yes, Senator, this is Jeff Lyash, from the Tennessee Valley Authority. I think this is an issue that is trending in a very positive direction. Actually, the largest support for the operating fleet in nuclear reactors around the plants comes from the local communities and governments where those facilities exist and serve because they have the deepest understanding of the technology.

The second comment I would make is that there is a growing sense, I believe, across the country and around the world and certainly reflected in this dialogue today, that confronting the issue of climate change and greenhouse gas reduction will require all the tools in the toolbox—nuclear, prime among them—and the technology is one of the safest ways to address what is a significant issue. I see that particularly in the younger generations and in the professional workforce that we're growing and engaging in this today.

So the direct answer to your question is that I think recognition that nuclear is one of the central ways we can cost-effectively, reliably, and resiliently reduce greenhouse gas emissions and create an economic development for the country at a policy level and then continued communication that the existing fleet of reactors we operate in this country are some of the safest generating facilities on

the planet and the U.S. nuclear program is the strongest nuclear program in the world.

Senator HICKENLOOPER. Great.

Mr. LEVESQUE. If I could add, Senator Hickenlooper, I'll just agree with Mr. Sell that these advanced nuclear plants, like X-energy and TerraPower's, offer a significant reduction in waste volume. That was one of TerraPower's goals at the start of our company, and that's really been enabled through advanced computer modeling and advanced materials. We have less waste at the end of the day. We also have much lower accident frequency.

So as we go to the public, which we will inevitably do as we license these plants, there will be public meetings as we go through this seven-year project. We will be talking to communities about the waste reduction, about the safety improvements.

And one other important thing: some of our messengers will be young people. There are many young people entering nuclear energy. We have young Ph.D.s at TerraPower who just committed their careers to nuclear energy because they want to fight climate change with nuclear energy. So we have technology improvements and we also have some great new voices that, I think, are going to help address these concerns.

Senator HICKENLOOPER. I could not agree more and I do appreciate—I am not sure which one of you mentioned the Colorado School of Mines, but I know a couple of the kids out there that are really engaged in studying the future of nuclear power.

But the fear does lead us into my one last question. Time always goes by so quickly in these. I thought I would ask Ms. Roma. You highlight the dominance of Russia and China in the new-build reactor market. How can we take advantage of the increasing export opportunities for nuclear energy and in a real way, I think, push back on both China and Russia trying to market autocratic government as being the better way around the world? I think this is an opportunity where we can really push back on that.

Ms. ROMA. Yes, I completely agree, thank you.

First, to your earlier statement about fear and consent-based siting, I have been doing licensing of new nuclear facilities for 17 years, and I can tell you that it's really hard to build any facility in a state and local community that don't want it. And so, engagement and making sure you're building it where people want it and that they support it and that everybody is brought to the table to be informed in that discussion is critical to deploying successful projects.

Turning to how the U.S. can become competitive overseas, other countries want a U.S. option. They don't have one. I was recently looking at a map of Africa that kind of laid out every country that is looking at deploying nuclear and what their plans are for doing that and who they're talking to. Every single country has either an agreement for nuclear cooperation in place with Russia or with China or both, none of them have any in place with the United States. The same is true—I was on a presentation where people from Southeast Asia, from Indonesia and Vietnam, were talking about the considerations that they have when they're looking at what technologies they're going to select and they said Russia and China are already coming and talking to us and you guys aren't.

And so, it's the industry going out, but the industry can't do it by themselves. TerraPower and X-energy can't go to a foreign country by ourselves and say, oh, can you build my reactor? It needs to be in coordination with the U.S. Government and creating this real, genuine kind of "team USA," using U.S. innovators and teaming them with the other tools that the U.S. Government has in its arsenal to go and become competitive.

Senator HICKENLOOPER. We agree and thank you all. I am out of time, but I will submit my other questions so they will be in the record. Thank you so much.

The CHAIRMAN. Thank you, Senator.

I am going to take the privilege, if I can, to ask a question before I go to Senator Daines because I had to step out for a minute.

Mr. Lyash, you and I had a good conversation. I really enjoyed it very much. I was just fascinated by the mix, your portfolio mix, for TVA. But also, we know that nuclear is emissions-free and plants have baseload attributes and proven track records of complementing variable energies, like renewables—I think you all do it all. But without new construction and the preservation of the existing nuclear fleet in the U.S., achieving a sustainable energy system will be more challenging and expensive as more renewables come online. Every year in the U.S., nuclear-generated electricity prevents more than 506 million metric tons of carbon dioxide from entering our atmosphere.

So if we are serious about using all-of-the-above and doing it right and reducing our emissions, what actions should Congress take to ensure that additional nuclear power plants do not suffer premature shutdowns? And you can give me the age of your fleet and how you have been able to maintain and operate at the capacity you have?

Mr. LYASH. Thank you, Senator. I appreciate the question.

You know, I believe that incorporation of renewables is important. We're building a thousand megawatts of solar a year, but nuclear makes that possible. That diverse fuel supply, that reliable resource, that high amount of carbon-free energy, backstands the renewables that we're adding. Your question about the existing fleet, we have the best performing nuclear fleet in the country, or in the world, and these plants are at the peak of their performance over the 50-year life of the industry.

The CHAIRMAN. What is the age of your plants, average age of your nuclear?

Mr. LYASH. Our plants are on average about 40 years old. We've extended the life——

The CHAIRMAN. How much life do you have left in them?

Mr. LYASH. I believe these plants can operate to 100 years. We are——

The CHAIRMAN. Unbelievable.

Mr. LYASH. We are extending the lives currently from 40 to 60 and we will move 60 to 80 and I believe, ultimately, we'll be able to extend past that. We can do that because we recognize the full value of these plants. One of the issues the fleet is facing——

The CHAIRMAN. Let me ask you—I hate to interrupt you, but why is the U.S. fleet then, why are we decreasing? Why are we taking them offline?

Mr. LYASH. Yes, because in my view, in the organized markets, we don't recognize the full value that a nuclear plant brings. We have short-term focused energy markets and very short-term, three-year focused capacity markets that don't recognize that nuclear plants can operate for decades at 98 percent reliability. As was mentioned earlier, they have a captive and secure—

The CHAIRMAN. You are saying the power generating companies themselves today, as we have them, you know, different companies I have in my state, my area, and everybody—but they are just not, basically, utilizing fully their nuclear fleet or—?

Mr. LYASH. That's correct. They don't—the markets don't recognize the full value. In order to correct that in the organized market, it's going to take action.

The CHAIRMAN. Because all we hear about is, well, as the fossil plants decrease, then we have to come on with renewables. Well, we know renewables do not have storage, so they are not baseload, but then the only baseloads I have ever known to be totally baseload were nuclear and coal, both fuels are right there.

Now gas has replaced an awful lot of the coal fleets and it seems like it has been more competitive, cost-wise, against nuclear. So it is replacing nuclear and coal—gas is. That is what we are seeing in the national market.

Mr. LYASH. Gas is certainly an important resource and I agree it is displacing coal. We should be aware though that gas, although it's valuable and it's an important bridge fuel, it still emits carbon dioxide as an effluent. Nuclear does not. Nuclear adds tremendous economic impact to the communities where those exist. A nuclear unit, on average, probably produces about a billion dollars—

The CHAIRMAN. And the cost of your nuclear? You are selling your nuclear power at what price?

Mr. LYASH. Our nuclear power is the second lowest-cost resource on the system. Our hydroelectric is the lowest. Nuclear is the second lowest.

The CHAIRMAN. Lower than gas and lower than renewables?

Mr. LYASH. It is.

Gas has approached nuclear power prices for us, but not surpassed them and—

The CHAIRMAN. Wind and solar?

Mr. LYASH. Both higher than nuclear.

The CHAIRMAN. I'll be darned.

Mr. Sell, do you have anything on this since you are right in the throw with things?

Mr. SELL. No, it's a great question that I know the Congress and the states have struggled with. Fundamentally—

The CHAIRMAN. We never hear—we don't talk, you understand, all of us here—we don't hear about nuclear. We don't talk about nuclear and it has been around. We have been running our whole military for what, 50-plus years?

Mr. SELL. Yes.

The CHAIRMAN. But yet, we don't even talk about it. All we are talking about—and I like renewables, we have renewables in my state. Every state has renewables. But nuclear really does the job, 24/7.

Mr. SELL. The issue has become, in the United States, as we have deregulated the markets—and appropriately deregulated them—we have a market design failure. In each of the individual states that regulate their electric market—

The CHAIRMAN. You are talking about merchant, right? Merchant plants?

Mr. SELL. Well, it's not just merchant plants. It's a market design that does not value the number-one attribute that nuclear power gives, which is 24/7 baseload, emissions-free generation. That has a tremendous value, which nuclear operators are not compensated for in the marketplace. And as a result, you've seen good, operating plants, producing power at very low cost, shut down—not in the TVA region, but in the Midwest region—when they were in a perfect condition to continue to operate. And it's really an issue that the Congress, I hope, can work with the states to resolve.

The CHAIRMAN. Thank you. My time is up.

Senator Daines.

Senator DAINES. Chairman Manchin, I appreciate your curiosity on nuclear. I think you made some really great points. And this is a nuclear option both sides might agree on, actually.

[Laughter.]

Well, speaking of nuclear, currently Montana does not have any nuclear generation sites. However, the Montana state legislature, which is in session as we speak, is working on a few bills that would make it easier for Montana to build a nuclear energy site, and a study replacing some old coal-fired boilers with new advanced nuclear reactors. In bringing nuclear energy to Montana, it would help create more high-paying jobs, as we know. It would further diversify and balance our energy portfolio, and with Montana losing important baseload power—as the Chairman just talked about the importance of baseload and affordable, reliable power—we are losing the power. We are losing these high-paying jobs, and as we are adding new, clean, carbon-free energy like nuclear, it could help keep Montana powered for decades and help sustain rural communities and jobs that depend on it.

Ms. ROMA, there have been very few new nuclear energy projects built in recent decades and many of our laws and regulations are very outdated. What state and federal hurdles, like the ones in Montana, should we re-examine to help spur more nuclear power production?

Ms. ROMA. There's a whole host of things to consider. One, for states, it depends on what the states' laws are. Some states have laws in place that outright ban nuclear and so those states either won't build nuclear or need to revisit those laws. Other states have in place renewable energy portfolios that recognize the carbon-free benefits that renewable energy brings. Some expand the definition of power generation that can fit into that window to include nuclear, others do not.

I suspect that as states actually look at how they're going to decarbonize their grid and have a diverse energy portfolio—because you have to realize that even if you have tons of great wind in your state, you don't want to get 100 percent of your power from solely wind. That's putting all your eggs in one basket and it's a pretty dangerous strategy for power generation sources. We need to focus

on diverse energy portfolios. So keeping in mind, how do you get that diversity while still meeting your climate goals is probably—and then how do you, kind of, work down from there—is probably a pretty strong objective.

From the federal level, there's a whole host of things to be done. I think for advanced reactors, really continuing to support the demonstration projects with TerraPower and with X-energy and then the Advanced Reactor Demonstration Program is also supporting a number of other advanced reactor companies. I think the most important thing to remember is, in the United States we can build a demonstration facility that can also serve as the first commercialized facility. It makes it a lot easier to sell something to other states and across, you know, into other countries, if we have a demonstrated technology so that people know what they're buying, know what the costs are associated with it, and know what the benefits are. So doing things to support research and development, doing things to support the advanced reactor companies, support innovation and then any kind of incentives to help take the sting off of deploying first-of-a-kind type facilities, such as loan guarantees or cost sharing would be very helpful.

Senator DAINES. Ms. Roma, thank you.

Now, let's assume we solve the nuclear issue here. We start building plants. I have another question though, that relates to what do we do about the uranium supply because we import 90 percent of our uranium from places like Russia, Kazakhstan, and Uzbekistan. This is despite the fact that we have ample reserves of recoverable deposits throughout the western United States and even in my home State of Montana. In fact, back in the '80s, the U.S. was a leading global producer of uranium and produced almost all the fuel that we needed to power a nuclear fleet, but now our production capabilities are at risk and we have ceded global leadership to foreign countries. This has caused the U.S. Commerce Department, in fact, in 2019, to determine that uranium imports threaten the national security of the United States.

Mr. Melbye, uranium can be found with other critical minerals. How can we better coordinate domestic mining to increase both uranium as well as other critical mineral production?

Mr. MELBYE. Senator Daines, you're exactly right. Many rare earth elements and minerals, they occur geologically with radio-nuclides, like uranium. So the uranium industry actually possesses the facilities and expertise to actually handle and process these rare earth minerals alongside of uranium operations. In fact, the licensed uranium facility in Utah is doing just that, and being part of the rare earth element story and trying to reduce our reliance on those elements, those critical minerals, from trying to pull that away from China and Russia, so—

Senator DAINES. And when we think about that, as being global stewards of the environment, we have some of the most stringent mining environmental laws in the world. We should be mining more here in the U.S. instead of depending on foreign countries that have less stringent standards.

Mr. Melbye, could you briefly describe how 21st century mining practices are beneficial to the environment, for jobs and our national security?

Mr. MELBYE. Well, Senator, you know very well in your state with such a mining tradition, the 21st century mining companies today have not only embraced the highest standards of health, safety, environment—we're setting the bar for around the world. So if we push mineral production offshore to other countries, we can't guarantee that those are going to be mined as responsibly as they are here.

I also know that the investment community, through ESG practices, is continually measuring us on our attention to our local communities, the health of our workers, our social responsibility in the places where we operate. So I think today we're a global standard for responsible mining in the United States and we should do more of it right here.

Senator DAINES. Thanks, Mr. Melbye.

Senator BARRASSO [presiding]. Thank you very much, Senator Daines.

Senator King.

Senator KING. I have been listening to this discussion. I came late. I was in another hearing. But the problem I have always understood with nuclear power is it is prohibitively expensive to build. Plants that are 40 years old that are fully amortized can compete with other forms, but a new plant—of the figures I remember and I may be somewhat out of date, about \$5 million a megawatt for a new nuclear plant, \$500,000 a megawatt for a gas plant, about \$1.5 million for a wind project. Nuclear power just is not remotely competitive economically in terms of new plants. Now the key, it seems to me, is innovation and development of these new alternatives that can bring that cost down but, I mean, I do not see how we can be having this discussion, at least about new conventional nuclear plants because the cost just is not even in the ballpark.

Am I wrong, Mr. Lyash? What is the cost per megawatt of a new nuclear power plant today in the United States?

Mr. LYASH. Well, Senator, the initial capital cost of new nuclear power is certainly higher, that initial capital investment, than a number of other generating sources.

Senator KING. It is not only higher, it is massively higher.

Mr. LYASH. But taken over—

Senator KING. Prohibitively higher.

Mr. LYASH. But taken over the lifetime of the facility, which extends 40, 50, 60 years, and levelizing that cost of energy, it's quite competitive. If we focus on nuclear power with a three-year time horizon like many organized markets do, it can't compete. But if you think of the total value of a nuclear plant and its lifetime, much like any other capital-intensive asset, and levelize that cost, it's actually quite competitive.

New nuclear designs are lower capital cost per kilowatt installed, shorter construction durations, and smaller sizes to reduce that initial capital investment, and like the existing nuclear plants, when thought of over their lifetime, are quite competitive.

Senator KING. And I appreciate that, and that is why I emphasized that I think demonstration projects, R&D, additional support for the new technologies that can bring that cost down, and also the construction period.

A question about ratemaking. Your point is well taken of the lengthy life cycle of 40 or 50 years. Do our current regulatory structures allow for that kind of spread-out of the cost because the problem is the bankers or the people that finance, they want their money back, maybe not in three years, but they want it back in sooner than 40 years. So is there a way to levelize the cost in terms of impact on the ratepayers?

Mr. LYASH. Yes, we have various regulatory structures in the U.S., which is part of the complication. For integrated investor-owned utilities, Southern Company, for example, that's building the Vogtle site, the regulator is providing oversight and working with them to do exactly that. For the Tennessee Valley Authority, we're public power. We continue to operate our plants quite successfully and could build new nuclear because, once again, we have the regulatory construct to amortize that over the life of the plant and levelize that cost and make it competitive. When you move to organized markets who, by their design, have short-term focus—day-ahead, week-ahead energy markets, three-year capacity markets—that regulatory structure makes it very difficult to build any investment that takes a high upfront capital cost—

Senator KING. Yes.

Mr. LYASH [continuing]. But delivers significant benefits in the long term. And I think if we're going to—

Senator KING. I understand that. I have done business in those markets and the problem is, they essentially discriminate against any capital-intensive energy form. They make natural gas pretty much the only alternative.

Mr. LYASH. Yes. And to Senator Manchin's earlier question, that's why the nuclear fleet struggles in those markets and it's an issue that we really need to correct to preserve that fleet.

Senator KING. Thank you very much.

Thank you, Mr. Chairman.

Senator BARRASSO. Thank you very much, Senator King.

Senator Lankford.

Senator LANKFORD. Thank you, Mr. Chairman. Thank you all for the testimony. It is extremely important to be able to have this dialogue.

Let me follow up with a basic question that I think we have talked about a little bit on the edge, but it has been interesting to do some reading on it. Mr. Lyash, is nuclear power determined to be base power or is it flexible power? Is it intermittent power or is it determined to be consistent?

Mr. LYASH. Senator, I think you could characterize nuclear power as either baseload or flexible depending on the plant design and its operating regimen. We have historically thought about nuclear plants as baseload and that's the way we tend to run them in this system. But the technology can fill any one of those roles if designed and located properly.

Senator LANKFORD. So, why would it be flexible? Why wouldn't it be baseload? What would be the design and the reason to be able to use it as flexible?

Mr. LYASH. I thought Mr. Levesque pointed out a good example where using thermal salt storage to store the power so it can operate as a baseload or you can use that storage capability as a peak-

ing resource. That's a good example of the flexibility in nuclear technology.

Senator LANKFORD. Okay.

Mr. LEVESQUE. That's correct, Senator, and that's one of the design goals of Natrium. And you know, when we talk about the economics of nuclear energy, better economics involve lower cost, that's enabled by new technology, but better economics for utilities is also related to the rate at which the power can be sold. In a plant like Natrium, being able to flex is going to be able to participate in capacity markets where the electricity will be at a higher cost. So in the past, nuclear has been baseload. New plants, like Natrium, will allow nuclear to participate in entirely new and more economically attractive markets.

Senator LANKFORD. Mr. Levesque, you talked a lot about having the power that is more of a smaller modular unit and not trying to create as large of a reactor. Tell me the advantage of that and how many facilities would have to be built to be able to make a difference on our power grid across the country.

Mr. LEVESQUE. So, to be clear, Senator, if we think about 2050, TerraPower envisions many small and large nuclear plants. Today, most nuclear plants are gigawatt-scale. And yes, we're talking about building smaller plants on the order of 300 megawatts per station now. That's what customers are looking for as they retire coal units, as we work nuclear into an established grid in countries like the U.S. and Europe, where there are developed grids. But certainly, as we prove out these first units as 300 megawatts, we anticipate growing the Natrium output back up to gigawatt-scale.

And again, if we think about 2050, we imagine many, many nuclear plants around the world. New 300-megawatt units and also new gigawatt-scale units as well, providing both electricity and process heat.

Senator LANKFORD. Mr. Levesque, let me ask you, when you say about many, many—give me a number. How many are you talking about? To be able to cover the United States by 2050, how many facilities would have to be built that are nuclear to be able to cover our energy needs?

Mr. LEVESQUE. Yes, it would be scores of plants. It all depends on—

Senator LANKFORD. More than ten?

Mr. LEVESQUE. Certainly, certainly scores of plants—

Senator LANKFORD. More than 100?

Mr. LEVESQUE. Yes, the opportunity for these advanced reactors is in the hundreds. I mean—

Senator LANKFORD. So are we talking a thousand? Are we talking a thousand that would have to be built by then?

Mr. LEVESQUE. Certainly hundreds between now and 2050 and that's why companies like TerraPower and X-energy are bringing so much private investment because we plan to sell and deliver hundreds of plants. That's how we'll get the return on investment.

Senator LANKFORD. To get to zero emissions by 2050, does anyone have a good idea how many facilities we would have to build by 2050 because we have talked a lot about wind power and solar power and how many acres that would cover, and actually, how

many entire states that that would have to cover to be able to do that.

How many nuclear facilities would we have to build to be able to get to that point by 2050? Does anyone have a good number for that?

Mr. SELL. I do not have a good number, but when you're talking about zero emission, that's increasing the entirety—eliminating the entire coal fleet, eliminating the entire natural gas fleet, and eliminating the industrial—or converting the industrial heat use, which is 90-plus percent fossil fuel, all to non-emitting baseload technologies. And that's going to require hundreds of plants, hundreds of gigawatts of plants over the next 50 years. Far greater than we operate, basically 100 gigawatts of plants now in the United States that were built between 1960 and 1995. We're talking about doing a multiple of that between now and 2050 in order to get close to achieving the kinds of decarbonization goals that you've outlined in your question.

Senator LANKFORD. And each one would cost about how much each?

Mr. SELL. For the X-energy plant, we're going to be competitive with the price of natural gas. So we have a price at less than \$50 per megawatt-hour on a go-forward basis.

Senator LANKFORD. Okay, thank you.

Mr. Chairman, thank you.

Senator BARRASSO. Thank you.

Senator Cassidy.

Senator Cassidy, are you available? He may have had to go to vote because we are in the middle of a series of votes.

While we are waiting for the Chairman to come back—we have four votes going on and the Chairman was going to do the end of the first vote and the beginning of the second vote. I voted already in the first vote. So I am going to go with additional questions and we will then await the Chairman.

Ms. Roma, the world is looking to expand the use of nuclear energy to meet our environmental as well as our energy goals. Why is the United States' leadership in the nuclear energy sector critically important? And can you also talk about what the consequences would be of losing nuclear deals to, say, Russia and China?

Ms. ROMA. Sure. It's critically important for the United States to be a global leader because that's where we've been and we've had huge dividends. It's prevented the spread of nuclear weapons. It's ensured that U.S. safety standards that come out of the U.S. Nuclear Regulatory Commission are widely adopted around the world, setting the gold standard for how you should regulate nuclear power plants to make sure they're run safely. It gives the United States a voice on nuclear safety and security purposes and allows us to strengthen and further develop relationships with countries that are building nuclear power plants that aren't just necessarily longtime U.S. allies, but allies that we're trying to establish further relationships with and that happened more recently with the UAE, where they didn't build a U.S. reactor design, but a number of U.S. companies helped support standing up that program. And that sig-

nificantly influenced the safety standards, the implementation of the nuclear safety culture.

I think that's something that we don't talk about very often when we talk about how important it is in running a nuclear power plant, but that's the idea that anybody within an organization can raise the safety issue, no matter what tribe you belong to, no matter what position you have within the plant. And in some of the places where we're building nuclear power plants, that entire concept is a foreign concept to them. And so, kind of embedding that at the beginning of a program, making sure that when countries that are new to nuclear and developing nuclear, that they do it safely and in a way that makes sense.

From a geopolitical standpoint, when we look at Russia and China, we have to look at not what are they just doing with nuclear, but what are they doing generally. Russia, historically, has treated its work in foreign countries as a geostrategic objective, where it can go and exert its influence, and by building, owning, operating, and controlling the major source of someone's power supply. I mean, one of the things that we talked about a little bit here when we think about nuclear is yes, it's expensive, but it's also immense. It's huge amounts of electricity for plants that can operate for 100 years. And so, when you look at building that much electricity in a country, if you have Russia who builds, owns, operates it and can shut it off, they now have a leverage over a foreign country that they didn't have before. That's probably a more aggressive tactic but it also allows them to establish a further, deeper relationship with that country as well.

For China, you know, they see an economic opportunity, but one of the things that I think is a concern is when China also builds, owns, and operates a nuclear power plant in a foreign country that it's financing—you know, the Egyptian reactors that Russia is building, it's financing for a 30-year finance period for a two percent annual rate of return, to the tune of like, I don't know, \$20 billion. When China offers the same thing and all of a sudden, a country in Africa can't make due on its payment, China has the ability to kind of foreclose on that and then exert its economic interests further in the country by taking over their power supply.

The United States doesn't do that. That's not how we operate. And we need to be able to offer other countries an option that isn't as predatory and that is more benign, while at the same time also hugely economically beneficial to the United States.

Senator BARRASSO. Thanks so very much.

Senator Hoeven.

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

My first question is for Mr. Melbye, and that is, in your testimony you mention the national defense requirements for U.S. uranium, including nuclear deterrents—and in North Dakota that is certainly the mission of the Minot Air Force Base. We have both the B-52s with the nuclear capacity as well as the ICBMs. And so, my first question is, we need an industrial base, obviously, to support military uranium requirements, but are the defense needs by themselves enough to create enough demand to sustain the required industrial base?

Mr. MELBYE. Actually, the easy answer is “no.” I think, you know, the combination of commercial nuclear power and defense needs can be complementary to each other. We’ve seen our defense needs met by stockpiles of uranium and fissile materials that were built up all the way back to the 1950s and ’60s. And so, we haven’t worried much about availability of future supplies, but we do know that these are finite and diminishing inventories, and those within the Defense Department that are looking out not only at our existing fleet of aircraft carriers and submarines, but new future deployments, are concerned that we could lose that domestic ability to produce not only uranium, but conversion and enriched uranium in support of our defense needs.

So fortunately, with robust commercial nuclear fuel markets at home and abroad, you know, this doesn’t have to be solely on the back of our defense budgets, but can come out of the commercial nuclear fuel cycle.

Senator HOEVEN. Do we have enough industrial demand—commercial demand—to maintain a source here or are we reliant on other countries?

Mr. MELBYE. Well, we have the demand, if you look at nuclear generation globally, I think we’re back to pre-Fukushima levels of nuclear generation and hence, uranium demand, so that’s certainly not a problem. It’s just the period of low prices, which we’re now only beginning to come out of. We need to maintain that domestic capability. We’re coming awfully close to losing it, but the infrastructure and the natural resources and the people are still in place and can ramp up quite quickly. I think the uranium reserve, if DOE can stand that up quickly and get it going this year, it was a bipartisan support of the budget for this year, and we get it funded in future years, that’s an excellent stimulus to get this industry back going, not only for commercial nuclear power, but defense needs as well.

Senator HOEVEN. Mr. Levesque, I would like to ask you the same questions. Where are we in terms of the supply and our ability to produce the uranium that we need and do you have recommendations on steps that should be taken?

Mr. LEVESQUE. Yes, certainly, Senator.

You know, TerraPower’s designed Sodium will require high-assay low-enriched uranium, which is the same uranium that we’re hearing about from, you know, mines in states like Wyoming. But I wanted to point out that these new technologies, like Mr. Sell was mentioning as well, require a higher level of enrichment. So not only do we need to, you know, reinvigorate things like the mining infrastructure, but we do not have enrichment capability in the U.S. today to produce HALEU, high-assay low-enriched uranium. So TerraPower and X-energy are working with the Department of Energy to identify a source of HALEU for our demo units, but again, we plan to sell many, many, hundreds of these X-energy and TerraPower reactors. And for that, we’re going to need not just uranium supply, but we’re going to need enrichment capability, U.S. enrichment capability, for high-assay low-enriched uranium. Our partner, Centrus Energy, has a small pilot project going on today to demonstrate that HALEU production, but we definitely need to ramp up that capability in the U.S. if we’re going to be ready to

provide hundreds of plants in the U.S. and worldwide that are fueled by high-assay low-enriched uranium.

Senator HOEVEN. Thank you.

Ms. Roma, your thoughts as well in the time I have remaining here.

Ms. ROMA. So it's critically important when we think about our energy needs that we also think about energy security and independence. Anytime you build a power source you need to be able to make sure you have your fuel nearby. The entire front end of the fuel cycle has been degraded when we saw the decline in the domestic nuclear power industry in the United States, the mining industry, the milling industry, the conversion industry, and the fuel fabrication—we need to be able to have these capabilities. The great news is, it's not a supply problem. We have immense amounts of uranium in the United States and we need to make sure we keep these capabilities on hand and fresh and sometimes, I think, as we saw most recently with the N95 mask shortage, sometimes you don't know you need something until you can't get it, and we just don't need to be in that situation with uranium.

Senator HOEVEN. Thank you, Ms. Roma. Thanks to all three of you and thank you, Mr. Chairman.

Senator BARRASSO. Thank you, Senator Hoeven.

Senator Murkowski.

Senator MURKOWSKI. Thank you, Mr. Chairman. Thank you for this hearing. I so appreciate the opportunity to focus again on the benefits of nuclear and, particularly, advanced nuclear reactors. I think we were able to accomplish some good things in this Committee last year and we want to be able to continue to build on those efforts.

I want to focus my questions this morning on some of the regulatory matters related to microgrids. So, I don't know, perhaps this is a question best asked for Ms. Roma. We have several microreactors that are in pre-application review with the NRC. One company, Oklo, has an application accepted for review under the combined license (COL) approach. The issue is the regulatory structure equates an operating permit with a specific site there.

So what should we do with this? Should Congress act to create new exemptions for microreactors so that a single design can be permitted for multiple sites? How can we, again, allow for an approach that will ensure greater commercialization opportunities for microreactors? And I pose that to Ms. Roma, but if there are others that wish to respond to that, I would appreciate it.

Ms. ROMA. I could start off and then maybe the others can hop in.

So the NRC does have a design certification process, but the NRC regulations that they stood up were for large-scale, light-water reactors and they envisioned a very slow and long process where a company applied for a design certification. Once the NRC reviewed and issued the design certification, which can be a five- or six-year process, then a company could apply for a site-specific combined construction and operating license application. It could also apply for an early site permit where the NRC would do early environmental review of a site and then it could apply for the COL and then get the COL. That whole process combined, which is prob-

ably what the NRC's preference would be for anybody doing licensing, can take decades.

Senator MURKOWSKI. Right.

Ms. ROMA. And it is cost prohibitive and doesn't make any sense, particularly for designs like microreactors, which have very, very small footprints, both from a public safety standpoint and from an environmental standpoint. And the NRC has been really looking at its regulations to figure out how we can right-size these for these types of facilities, but they're bringing their large, light-water reactor mindset, which is really a round peg in a square hole.

And so, what Congress can do is support the streamlining or even help check certain boxes so that the NRC can do a more efficient—not a less robust—a more efficient review, commensurate with the size and impact of these facilities. That would be very, very helpful.

Senator MURKOWSKI. Well, I appreciate that. I have tried to outline the potential that we would have in a place like Alaska, where, I think, we have some interesting applications for microreactors and what we might be able to deploy. But when you look at the structure within the regulatory commission, it is just not set up to help facilitate deployment in a state like Alaska, where you have some pretty remote communities, some pretty remote sites that would benefit from exactly this type. So you are suggesting we need legislation. NRC says that they are dealing with what they are going to deal with.

Did one of you—Mr. Sell, nice to see you.

Mr. SELL. Senator Murkowski, there is something interesting going on that I think is relevant and that, as you may know, the Department of Defense has a program to design mobile microreactors for four operating bases.

Senator MURKOWSKI. Right.

Mr. SELL. Our company, X-energy, is one of the companies involved in that design effort. That reactor will be deployed on a prototype basis by 2024. And although it will be licensed by the Department of Energy, the NRC regulators are embedded into the program. And so, there is an opportunity for the NRC to observe—to learn and to take lessons out of that and apply those to the commercial applications like Oklo and others. It is a rapid technology development program and the licensing process to go along with that is having to evolve to go with it, to move at the appropriate level of speed. And I think real lessons will come out of that effort.

Senator MURKOWSKI. My observation is that we are at that point where we are building out the prototypes—we know what it is that we need to do. The thing that is slowing us down is the regulator, who has not caught up to the fact that this is not, you know, “your father's Oldsmobile” in the sense of what we have been building in this country in terms of nuclear facilities for so many decades.

Mr. SELL. I think that's true. I will acknowledge that the last number of years at the NRC and now, with Chairman Hanson, there is a strong commitment at the leadership level to be responsive to the laws that this Committee originated and passed, and reformed the process. And they want to do the right thing, but you know, sometimes changed management in a large organization is challenging and we're going to continue to push on.

Mr. LEVESQUE. I would agree. I would agree, Senator. The leadership has been very progressive and I think legislation that empowers the NRC to consider new approaches toward regulation, that's really helpful. And finally, I'll add that, you know, I've worked around the world in nuclear energy and been asked many times in other countries, what does the NRC think? The NRC is the worldwide standard for nuclear safety and if we think about a "team USA" approach, if we have advanced reactors that are licensed by the NRC, the U.S. is going to be so competitive worldwide offering these reactors as options to Russian or Chinese technology.

Senator MURKOWSKI. Thank you.

Mr. Chairman, thank you. I have additional questions that I am probably going to submit for the record, where as you know, we are bouncing in between votes, but this is such an important hearing and I really appreciate that.

Senator BARRASSO. Thank you, Senator Murkowski.

Senator Cassidy.

Senator CASSIDY. Hey, thank you all and, again, it is a great hearing. I, too, have been bouncing between committee hearings and votes, so I apologize if there is redundancy in what I ask.

Mr. Sell and Mr. Levesque, what will be the cost per megawatt-hour both—first, how much is it going to cost to build one of these? What is their capacity? After you have the flow down and you have built four or five, what can we expect the cost to be then and how much will it cost to operate per megawatt-hour compared to other forms of energy?

Mr. LEVESQUE. Okay, Senator.

The first units, these demonstration units that TerraPower and X-energy are working on, they will cost several billion dollars each because they have all of those first-of-a-kind costs that Mr. Sell was mentioning, the first-time licensing, the first-time design and also, frankly, you know, the U.S. supply chain and the U.S. infrastructure is out of practice. So those first demonstration plants will cost somewhat more because of those first-of-a-kind and learning curve things. And that's what makes it ideal for us to have the ARDP, which is public and private funding—kind of, you know, overcoming this speed bump to get us into the next technology.

But after the demonstration, we see plants that are going to be, because of the technology differences, again, because of things like lower pressure, we're going to have plants that are totally competitive with natural gas. They're going to be safer and, again, in the case of Sodium, it's going to be able to flex its power and participate in electricity markets that are more lucrative than what plants can—

Senator CASSIDY. But Mr. Levesque, I mean, just to put a point on it, do you have—okay, you've built your first five. So then do you have a projected cost of what it would cost then because I think Mr. Lyash was involved with CB&I. They attempted to do something for Southern Company and initially had to rebuild all the training of the workforce, but it still ended up being incredibly expensive and it never got over that initial bump.

By the way, I am supportive of it. I want this to happen. I am just trying to figure out what the landscape looks like.

Mr. LEVESQUE. Yes, Senator. The landscape is this: the U.S. is rusty, Russia and China are building many units.

Senator CASSIDY. No, I get that.

Mr. LEVESQUE. Yes.

Senator CASSIDY. But do you have a projected cost after you have done your first three or four and you have kind of worked out the kinks?

Mr. LEVESQUE. You know, plants that are of this 300-megawatt size should certainly cost less than \$1 billion. It'll be competitive. I also want to point out, by going to some of these new plants, the number of U.S. jobs and the invigoration of the supply chain should increase. Light-water reactors today, you have to go to Japan to get super-heavy forging for the pressurized water reactors.

Senator CASSIDY. Let me just ask, because I only have a couple minutes left.

Mr. Lyash, I apologize if I am mispronouncing your name, but when I was listening earlier you seemed to be talking about some challenges. I didn't hear the whole conversation, but you were talking about why we are decommissioning some of our existing nuclear. To what degree do production tax credits and other incentives to allow renewable energies to sell below market—to actually pay people to take their energy—to what degree has that played into the demise of the decommissioning of some of these plants?

Mr. LYASH. Senator, I think it plays significantly into it. You know, as Mr. Levesque was saying, these plants are high capital cost, but when you levelize the cost over the life of the facility, 20, 30, 40, 50 years, they produce quite competitive levelized costs of power, but they deliver more than that. They deliver reliability, fuel diversity, fuel security, huge amounts of zero carbon electricity. These don't have—

Senator CASSIDY. I am totally getting that, Mr. Lyash, again, but just back to the point.

Mr. LYASH. Yes.

Senator CASSIDY. We are going to be making decisions regarding tax breaks for renewables, some of which are quite mature, but nonetheless, advocates are still advocating for continuation of the tax breaks. So to what degree are these tax breaks playing a role in the decommissioning of a nuclear power plant in Illinois, for example?

Mr. LYASH. Directly, because these attributes of nuclear power aren't rewarded by the market, and wind and solar have tax credits. Production tax credits or investment tax credits, they artificially depress the price of that energy below the nuclear plant and lead directly—contribute directly, I should say—to a non-cost-competitive position of those plants, not because—

Senator CASSIDY. I once heard somebody say that, paradoxically, renewables in the current environment, by forcing the construction of baseload facilities, but simultaneously forcing the decommissioning of nuclear power plants, which would be the natural baseload, are actually paradoxically increasing global greenhouse gas emissions. Maybe too strong of a statement, but is there some rationale to that?

Mr. LYASH. There is. The intermittent renewables with the depressed prices due to production tax credits and investment tax

credits are forcing high energy baseload units into a non-competitive position. The retirement of those baseload units makes the addition of renewables not possible, or at least not possible without significant adverse effects on reliability. These things have to move together in balance to have a system that is both economic and reliable in the long term.

Senator CASSIDY. One more question, because I am over my time. Mr. Levesque, Mr. Lyash points out that yes, initially your cost is high, but if you levelize it over 60 years—I think there is a nuclear power plant in Louisiana that may go for at least 60 years. What is the actual cost, once you have done your construction cost, what is going to be the cost of operating and maintaining one of these plants, because it does sound like your initial construction plant is still going to be more expensive than a natural gas, but what was just implied in that, is that your operation and maintenance could be less than another form of energy?

Mr. LEVESQUE. Yes, Senator, certainly cheaper than natural gas on that levelized cost and, you know, with automation and technologies, the required staffing at the plant to operate the plant should be much lower. And again, if we secure these U.S. fuel and enrichment sources, that'll give us greater control over the life cycle fuel cost.

Senator CASSIDY. Got it. Okay, I yield back. Thank you.

Senator BARRASSO. Thank you very much, I appreciate it.

Mr. Sell, you know, I appreciate your support for the establishment of a uranium reserve. You talked about that. Your written testimony highlighted the need for a specific type of uranium, a high-assay low-enriched uranium. You state that the timelines set in the Energy Act of 2020 are not aggressive enough to meet your needs. I think you stated you need this material by 2024.

So will the Department of Energy be able to supply the necessary material to meet your needs, and if not, how are you going to secure the material?

Mr. SELL. Well, Senator, it's really not the Department of Energy's total responsibility. There is a commercial market for HALEU, and Centrus is a private company, and they have a pilot project that is funded by the Department of Energy to begin the production process. But I'm going to need about three tons of high-assay LEU in the 2024 timeframe in order to start the fuel-making process for our first plant at Energy Northwest. And so, I think there's going to be a number of initiatives that will have to be pursued in order to increase the availability of HALEU for that first plant.

Senator BARRASSO. Thank you so much for that answer.

Mr. Levesque, is there anything that you would like to add to that?

Mr. LEVESQUE. No, Senator. We have a very similar need with TerraPower's Sodium reactor.

Senator BARRASSO. Thank you.

Senator Manchin.

The CHAIRMAN [presiding]. I am so sorry, Senator Barrasso. They are still on the first vote, if you can believe it. I thought it would have wrapped up when I went down, I could have voted twice and come back, but this is the Senate. Welcome to the most deliberate body in the world.

If I am repeating a question, you know, please forgive me and then let me know what you are thinking. I just thank all of you. I really believe we are missing a golden opportunity if we do not get back in action. And I think Mr. Lyash and I had a, like you said before, we had a good conversation and realizing how strong TVA is, but it is a whole different ballgame—the way it was created, who it is, how it operates—but they do it and do it so well. If it can work in that type of environment, it can work in the market environment too. But what I am understanding from what you all have told me is that starting with FERC, starting with regulatory, basically, in Washington, demanding that we have that type of dependable, reliable, and affordable power which is, basically, baseload. And you know, because we have had other things kind of freeze up and we have had other things kind of shut down, stop, and I think Texas is a wake-up call.

I am more concerned also too about the security. And I think nuclear can scare the daylights out of some people, thinking of the catastrophe. I remember Three Mile and how this happened. So they are saying, oh boy, if we have a cyberattack—I am going to let all of you comment on it—if we have a cyberattack, then we are really in a problem there because they can really melt this thing down and cause catastrophic—okay?

So Mr. Sell, if you want to start on that and then we will go right down.

Mr. SELL. Thank you for the opportunity.

The X-energy plant is intrinsically safe. So what does that mean? What it means, Senator Manchin—Chairman Manchin—is that our plant cannot melt down. What happened at Three Mile Island is physically impossible to happen in an Xe-100 plant.

The CHAIRMAN. Got it.

Mr. SELL. So is the plant safer? Yes, it's safer. But the more important thing is, we do not have to build all of the safety-related systems that a typical light-water reactor plant has to make. So we result in a much simpler plant that is more economic to build and more economic to operate. And that is why our plant can be built quicker, to be operated more cheaply, and therefore, it's much more attractive from an economic standpoint than traditional large, light-water reactor plants.

The CHAIRMAN. Mr. Melbye, do you have any comments on this? This is my last question.

Mr. MELBYE. Yes.

The CHAIRMAN. I just need to know how we can make sure that nuclear is allowed to do the job we know it can do. And right now, we are not in that mindset, is what you are telling me? It is aspirational. Everybody wants to stop this, stop that, and let's do everything with renewables and this and that and I understand. But we know it is not going to carry the load. It will not afford us 24/7, rain or shine, and to be the number one and be the superpower of the world in having the demand for power that we have taken for granted all these years. We have to continue in that mindset of energy independence. So anything, just a quick comment from all of you on that.

Mr. MELBYE. I'll just reiterate what you said about how Texas was a wake-up call for all of us. We have operations down there,

so we saw what happened firsthand and, you know, the resiliency, the 24/7 aspects of nuclear energy, the predictability of fuel cost. Gas is a great way to make electricity when gas is cheap, but we found out with \$18,000 electricity bills that when the price of gas goes up, it hurts that form of energy.

So nuclear can really be the complement in—and as you have all—

The CHAIRMAN. Did any nuclear go down in Texas?

Mr. MELBYE. We have four units in Texas. One did go down for a day, but was—

The CHAIRMAN. I thought the supply, the water supply line froze up, is what I understand.

Mr. MELBYE. So we were 75 percent up, but back to 100 percent after a day.

The CHAIRMAN. But if there would have been weatherization precautions taken, that should have never gone down.

Mr. MELBYE. They are already taking them.

The CHAIRMAN. Got it.

Mr. Lyash.

Mr. LYASH. Yes, Senator, I would just stress that nuclear, non-light-water and light-water reactors are going to be critical to maintaining reliability, economic development advantage, and hitting our environmental objectives. And I would suggest four things. First, action needs to be taken to preserve the existing nuclear fleet and to address this value that's not recognized by the organized markets that needs to be recognized. If we don't preserve that fleet, we cannot maintain or develop a leadership position in the world on nuclear power.

The CHAIRMAN. What do you know about the fleet, sir, because you have a tremendous amount of experience in this operation? What do you know, any of you all know, about the fleets that have been shut down or those that are being targeted to be shut down? Is there any other reason except market decisions that people are making right now that those should ever be shut down?

Mr. LYASH. No, the primary reason here is market decisions and it's a short-sighted view of the value of the plants.

The CHAIRMAN. Got it.

Mr. LYASH. And you must address that—

The CHAIRMAN. We will get on that. We can get into that real quick.

Mr. LYASH. The second step I suggest—you are already taking it—and that is to recognize the role of nuclear at a policy level in addressing long-term climate change objectives. The third is to support the development and deployment of advanced reactors, light-water and non-light-water reactors and I think the Advanced Reactor Demonstration Program is a step to doing that. I think more is going to be necessary to create this advanced reactor industry for the U.S. and to make it an export for the U.S. around the world. And the last is just to make sure that the regulatory and federal agencies that have to support extension of the existing fleet and licensing of new are properly focused and resourced to do just that.

The CHAIRMAN. Ms. Roma, do you have any comments you would like to share with us?

Ms. ROMA. Actually, Senator, I thought it was great that you started off with your cyber fear for nuclear because when you look at any critical infrastructure, nuclear power has the most advanced cybersecurity protections, and that is you can't hack it. Right? You can't cause any kind of harm in a nuclear power plant from a cyberattack, which is fantastic and just shows you how robust this technology is. When you look at advanced reactors, most of—

The CHAIRMAN. I hope you share that with the Federal Government and our Department of Defense because we get hacked every second of every minute of every day.

Ms. ROMA. They actually know that, yes.

Yes, well, and they try to hack nuclear power plants. It just doesn't work.

The CHAIRMAN. Good.

Ms. ROMA. There are just too many layers of defense and they're not attached to the grid.

The CHAIRMAN. Got it, yes.

Ms. ROMA. So any of the security systems aren't attached to the grid, which makes it really, really robust.

But from a safety and security standpoint, with advanced reactors, you know, a lot of them, they're small, they're buried underground, you know, you could do whole lots of bad things to them and nothing is going to happen because they're underground so they're not going to hurt anybody or harm anybody. But I think to your underlying point, right?—this is an important discussion and it needs to be based on facts, not fear.

And so we need to have this conversation. The American public needs to be engaged and make decisions that they feel fit what they need—carbon-free, safe power. And we can do that. We just have to keep—

The CHAIRMAN. Mr. Levesque.

Mr. LEVESQUE. Yes, Mr. Chairman, advanced nuclear is going to give you that reliability and resiliency that the current fleet has, you know, to sustain multiday tropical storms in Florida or the polar vortex in Illinois. Advanced nuclear is going to give you that kind of reliability, but it's also going to give you those safety and cost improvements that Mr. Sell and I have been describing.

The CHAIRMAN. Let me just say this and then I am going to go to Senator Marshall to finish up our meeting.

Just a lack of knowledge, a lack of education to the people. I have always believed because everyone, the life cycles of anything—so coal-fired plants, we knew what their life cycles were and they started ending the end-of-life cycle and it was time to deploy them out and cycle them out. So we think in the same terms. Well, it is not—what you are telling me—that is not the case. If they are properly maintained, they can go on and on and on with some technology changes, I guess is what I am understanding.

So if you are going from a normal plant, probably at TVA or any of you all, when those first came online, maybe you had a 40- or 50-year life to them. But you found out that you can extend those lives very, very safely in this environment. We have to now find out every nuclear plant that is on the chopping block right now and get to the CEOs of those companies and make them come here and tell us why they are taking offline something that should never have

been taken offline, should not even be considered to be taken offline and why we cannot build the rate in to make sure they are able to operate at that level. We can do that. That is our job here, for the sake of our country. That is what we are looking for.

You all have been invaluable today, and with that, I want to thank each and every one of you, but I want to turn to my friend, Senator Marshall, for his final round.

Senator MARSHALL. Yes, thank you so much, Chairman. It is great to be here with you all this morning. I was on my path to become a nuclear engineer when medical school interrupted it. So it is certainly a field that has been near and dear to my heart growing up. Watching Wolf Creek nuclear power plant in Kansas being built, I think, was an inspiration for a lot of young men and women to go into engineering and study math a little bit harder.

I think my first question will probably be to Ms. Roma. I am just shocked to see these nuclear plants being retired, in my opinion, prematurely. Everything that we are talking about, you know, what is an economical way to get to lower carbon, would say to keep the existing plants operating. What is leading to these being shut down prematurely? Who is making that decision? Who is driving that decision to shut these down ahead of time?

Ms. Roma.

Ms. ROMA. Yes, well, the nuclear power plants are businesses and, you know, they recover rates and get paid for the electricity that they generate and that's based on the existing market structure we have in the United States that just says how much does it cost to produce electricity over the next few years and they go with the cheapest and then they go to the next cheapest, the next cheapest until they're done. And so when you look at the price of natural gas, until about the 2008 timeframe, new nuclear was very competitive and actually dozens of nuclear power plants were planned because the price of natural gas was higher. Around 2008, the price of natural gas took a sharp dive down and then we discovered we can probably just leave it down there for a while, which all of a sudden made nuclear not economic anymore.

When you look at renewables, they're subsidized. They're intermittent—a huge, important part of the energy mix—but they're intermittent and they're subsidized and so nuclear just doesn't fit into the mix anymore. But the largest value that it has besides providing immense amounts of constant power is that it's carbon-free and secure and reliable.

Senator MARSHALL. Huh. Okay.

Mr. Lyash, I guess what I hear her saying is that it is probably a huge capital cost, obviously, to keep these plants—to keeping them going. So it is just cheaper to build a new coal plant or it is cheaper to build a new natural gas plant than it would be to rehab these and keep them going? Is it just economics?

Mr. LYASH. Yes, I think what was pointed out, that the markets aren't structured to reward the value of this, is right on target, but I think there's a deeper problem. It stems from a very short-term focus on our energy plan, that we're in the market buying whatever the cheapest energy is by our definition today, not recognizing that diversity in the energy supply, in terms of fuel, in terms of technology, in terms of the economy, long-term environmental objec-

tives, is how we really need to plan this energy system. It's the same conversation we had earlier with respect to uranium mining and enrichment, taking the long view and the global view. I think the same view needs to be taken of the energy mix in this country. And if you do that, technologies like nuclear emerge with a critical role to meeting our long-term objectives. And I think the markets need policy and they need signal and they need direction in order to establish that kind of balance.

Senator MARSHALL. Great.

Being a big defender of nuclear engineering for decades, you know, the question always posed for me was the disposal part of it. And as I think about electric cars today, I am equally concerned about the environmental impact of disposing of their batteries as well. And I am thinking of these big graveyards of electric batteries. And I know everyone is going to talk about future technology, and we are going to reuse it all. Is there anybody that has really seen any good environmental impacts of nuclear waste versus just the equivalent number of batteries we are going to have to throw away to make this worse? If this was happening today, not future, are there any good studies out trying to compare apples and apples?

Mr. LYASH. Senator, spent nuclear fuel is extremely well understood. We can store a lifetime of fuel ever used safely on the nuclear site that utilized that fuel. Alternatively, as a country, we could go to regional storage or monitored storage. Countries around the world have moved safely to geological repositories. The strength of nuclear, even in the face of the spent nuclear fuel, is that we understand it. We contain it and it has no impact on the environment.

Unlike what we're seeing, for example, with transportation, where we drive down the street with our automobile. We emit waste from the tailpipe. We're not sure how much. We're not sure where it goes. We're not sure what it's doing.

And so I think the nuclear waste issue is certainly not immaterial. It's significant, but it is not a safety issue and I think it's an issue we can solve in the long term.

Senator MARSHALL. I guess I am past my time, but I have been told we could take all the nuclear waste in the United States and put it on one football field and if we just had a place to do that.

So thank you so much and I yield back.

The CHAIRMAN. Again, let me thank each and every one of you for taking the time and effort to come here because it has been invaluable. I can tell you, you have helped me a tremendous amount and I think you helped our Committee understand better what we are facing and how we can, basically, decarbonize without basically killing ourselves, if you will, shooting ourselves in the foot.

So I will say this, members will have until close of business tomorrow to submit additional questions for the record.

The Committee stands adjourned.

[Whereupon, at 11:55 a.m., the Committee was adjourned.]

APPENDIX MATERIAL SUBMITTED

U.S. Senate Committee on Energy and Natural Resources
 March 25, 2021 Hearing: *The Latest Developments in the Nuclear Energy Sector with a
 Focus on Ways to Maintain and Expand the Use of Nuclear Energy in the United States and Abroad*
 Questions for the Record Submitted to Mr. Jeffrey J. Lyash

Questions from Ranking Member John Barrasso

Question 1: You suggested that the Department of Energy needs to do more to support additional demonstrations of advanced reactors. What else should the Department do to demonstrate advanced nuclear technologies, including small modular reactors?

Increased support for projects that are most ready for deployment could further an accelerated timeline of decarbonization goals. From a utility perspective, that means projects that have fewer uncertainties in areas that are important to safety and economics. Therefore, DOE could look to support projects that have mature fuel designs, few unique components requiring testing or supply chain development, and clear NRC licensing pathways. This will enable faster utility investment, which leads to more deployments and meaningful contributions to carbon reduction in the least amount of time.

Two examples of possible DOE support would be direct investment in SMR assets and entering into long term power purchase agreements with utilities. Such projects would reduce DOE's carbon emissions considerably, increase reliability and resiliency of DOE's facilities, create many good jobs, and establish U.S. nuclear technology leadership and manufacturing capabilities that enable a strong global export business.

Question 2: You have prioritized small modular reactors for initial demonstration. What types of non-water cooled advanced reactors would you consider in your long-term planning? Why?

TVA believes light-water small modular reactors are more ready for demonstration now and can therefore contribute to achieving decarbonization goals sooner than non-light water advanced reactor designs. We have come to this conclusion after a detailed review of many designs conducted over several years.

That said, TVA also remains interested in advanced reactors that use coolants such as gas, liquid metal and molten salt. We are particularly interested in designs that have low pressure, high temperature and high power density as these features give the design the greatest chance of being economical, because the reactor plant can be more compact and use less steel and concrete on a per megawatt basis. Higher temperatures allow for increased thermal efficiency (more electricity for the same reactor power level) in electricity generation, the ability to serve process heat markets requiring higher temperatures, and the ability to use thermal energy storage systems to make the reactor even more compatible with renewables.

TVA's Clinch River Site is available for building and operating more than one project, including different designs. As TVA takes a long-term view, there are clean power generation needs in the 2030s and 2040s that could be met by either light-water small modular reactors or non-water cooled designs. Having technology options to choose from would be ideal.

Question 3: The Tennessee Valley Authority (TVA) was recently issued the first early site permit for an advanced reactor. As an early mover, TVA is paving the way for other utilities considering advanced nuclear technologies. What advice do you have for other utilities considering advanced nuclear technologies?

TVA's Clinch River Site is indeed a success story – not only is it the only site in the nation to have an early site permit for potential deployment of small modular reactors, NRC's review was completed ahead of schedule, established an industry best-practice on use of audits, and included a risk-informed, consequence-based emergency planning approach important to the commercial viability of all advanced designs.

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TVA offers the following advice to utilities interested in new nuclear:

- Engage early. Engage with developers in design reviews, operability reviews, licensing reviews, and cost estimating. Engage internally with integrated resource planning to understand how new nuclear may meet your needs and provide feedback on those needs to developers.
- Prioritize investments and invest incrementally. Invest in reducing high risks early. For utilities, one of the most important decisions is to find a suitable site, sufficient to pass muster with the NRC and public.
- If planning a First-of-a-Kind deployment of a new technology, consider sharing costs/risks with others, including DOE and industry. A utility consortium is important to ensure the design becomes standardized to meet the needs of multiple projects/sites, and to avoid the risk inherent with an Only-of-a-Kind plant that would be challenging to find spare parts for and operate efficiently.

Question from Senator James E. Risch

Question: TVA's energy portfolio includes about 40 percent nuclear. Over the past decade we have seen a real change in economics for our existing fleet of nuclear reactors resulting in a number of reactors shutting down – many of them before the end of their useful life. What opportunities are there to keep existing plants operating and providing clean, reliable power to consumers across the country?

Continued operation of the existing U.S. nuclear fleet depends first on the economics of the markets where they operate. In many markets, the carbon-free generation from nuclear power is undervalued or not recognized. As you've mentioned, safe and well performing nuclear plants are being prematurely shut down. Plant owners must commit to the asset investments needed for long-term reliability. Finally, we need a license renewal process that is both predictable and efficient. While NRC has demonstrated schedule discipline in recent license renewals, there are still opportunities to be more efficient. One example is to allow a utility to apply earlier for its license renewals (today a utility must wait until a plant is within 20-years of its license expiration).

Questions from Senator Steve Daines

Question 1: Mr. Lyash, the Tennessee Valley Authority is at the forefront of new nuclear development. Having just experienced permitting a new nuclear plant, what specific federal regulations and laws unduly slowed development and what should Congress reexamine to ensure the next nuclear energy site is built quickly and safely?

The ongoing NRC rulemaking effort for "Alignment of Licensing Processes and Lessons Learned from New Reactor Licensing" contains many improvements to the licensing processes which will assist with deployment of new nuclear. One of the many important topics under consideration in this rulemaking is the optimization of the 10 CFR Part 52 change process for Tier 1 and Tier 2 design features during construction. A similar effort to provide an efficient change process for Part 50 applications, during construction but prior to the issuance of the operating license, would be of benefit by reducing the regulatory burden for non-consequential changes to the vendor design during construction.

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Question 2: Mr. Lyash, being a good partner and having strong local community support is critical when designing new energy projects. What lessons can other projects learn from your recent engagement?

As part of TVA's Early Site Permit application work, the TVA team developed a communication and engagement plan to demonstrate our commitment to protecting the public and to explain the scientific and engineering basis for using a scalable emergency planning zone. Early engagements with state and local emergency management agencies highlighted the need to address potential misperceptions. Engaging the public living in the vicinity of the Clinch River site, listening to their concerns and addressing them in our planning process was particularly important to the effort. TVA representatives actively sought public input in the project and provided immediate feedback. Inviting all residents within a 1.5-mile radius of the site, TVA held a public social gathering where employees and the public could engage in a candid dialogue. Attendees were also offered bus tours of the Clinch River site. From this event, TVA received valuable feedback from residents. For example, one neighbor said they didn't want bright lights from the plant shining into their house and ruining their night view. We evaluated this comment and have incorporated a requirement to shroud our lighting to minimize direct view by neighbors while still meeting safety and security requirements. Early engagement and candid dialogue helped establish what we anticipate to be a beneficial, long-term relationship with plant neighbors.

Question 3: Mr. Lyash, like 21st century mining practices, 21st century nuclear energy is much different than it was in the past. What is industry doing to engage with the American people on the safety standards, high-paying jobs, and community benefits of modern nuclear energy?

In partnership with organizations such as the Nuclear Energy Institute, the American Nuclear Society and the Department of Energy, the U.S. nuclear energy industry has worked together to create educational content that can engage Americans of every generation, no matter their familiarity with nuclear. Many nuclear plants, including ours, have opened their gates to the media and key leaders to see first-hand, the safe operation of a nuclear plant. There is a growing recognition of the industry's unwavering commitment to and focus on safety and reliability. Specifically, the U.S. nuclear power industry has consistently improved performance over the past 20 years. This performance manifests itself in many dimensions, including worker safety, public safety and plant reliability. Now, with advanced nuclear technologies, these units will be even safer and offer more flexibility and versatility while integrating better with other sources like wind, solar, and batteries. Finally, with regards to jobs and community benefits, America's nuclear plants provide more than just reliable carbon-free electricity to their local communities. They are economic powerhouses, creating and sustaining hundreds to thousands of jobs, supporting local businesses and generating millions in tax revenue that support local school districts, law enforcement, and other essential services. In fact, nuclear plants are often the largest taxpayers and the largest providers of charitable giving in their communities.

Questions from Senator Lisa Murkowski

Question 1: The Tennessee Valley Authority was recently issued an Early Site Permit by the Nuclear Regulatory Commission for its Clinch River site near Oak Ridge, Tennessee. This Permit allows TVA to build new small and advanced reactor designs at the Clinch River site and can help streamline the licensing review for building new technologies. How has this process helped you prepare for partnering with new advanced reactor companies?

The Clinch River early site permit experience has further prepared TVA to champion new and innovative efforts. The Early Site Permit application was first of a kind in several ways – technology-inclusive plant parameter envelope, risk-informed emergency preparedness, and the potential to deploy more than one design. We accomplished the Clinch River ESP by building a strong team and implementing best practices. These efforts have

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prepared us for the next phase at the Clinch River Site. Our site has lower risk and therefore is attractive to all developers who are eager to move aggressively toward commercial operations.

Question 2: What can other utilities do to prepare for these new designs and developments?

Utilities can engage early with vendors to provide end-user perspective that will inform the vendor designs early and help shape a product that can actually meet the market needs and utilities want to purchase. Often conceptual vendor designs lack the details needed to assess licensability, supply chains and operations/maintenance strategies that utilities require in their risk assessments before making investment in a specific design. Early engagement with developers on their designs help to guide the design process and achieve products that are sought by utilities.

Question 3: What steps can Congress take to ensure we maintain our existing nuclear plants?

Market reforms are needed in certain regions of the U.S. so that the attributes of nuclear energy are valued in the marketplace. In deregulated markets, capacity markets do not look long-term enough to properly facilitate electricity asset decision-making. Current policies and market structures are driving economics and operational behaviors that are degrading long-term electricity system reliability.

Congress should ensure clean and reliable nuclear energy is properly valued relative to the alternatives.

Question 4: As a utility, you will be the end-user for many of these new advanced reactor designs. What is needed to help you make the decision to include nuclear energy in your long-term planning?

First and foremost, the technology has to be available and cost competitive with other generation alternatives. While a diverse generation portfolio is advantageous from a utility perspective, resource planning processes will not select an advanced reactor design unless it is projected to be economic over the longer term and has reasonable certainty around cost, schedule and reliability once deployed. Mitigation of First-of-a-Kind risks, through government support or other financial arrangements, can help utilities make the difficult decision to deploy a new technology. For utilities, economic analyses and decision making are commonly risk-informed processes, so certainty and consistency in the valuation of carbon-free generation from nuclear power will also support future deployment.

To be considered in long-term planning, designers should focus on risk reduction. One of the largest risks is construction execution. The larger the project, the more execution risk there is. To reduce this risk, designers should avoid designs that are more than several hundred MWe. Further, as the grid changes, there is value in being able to better distribute generation, rather than have a large station at one node on the electric grid.

The utility industry needs help getting multiple designs to a high state of design maturity, including full-scale demonstration of multiple first plants, so that nuclear energy is available to meet the nation's needs by enabling many utilities to decarbonize their generation systems in the 2030s. The industry would also benefit from the Nuclear Regulatory Commission focusing its reviews of new designs on the aspects that are unique and important to safety. Finally, it is essential to have a design that is economical, with a levelized cost of electricity that competes with alternative sources of electricity generation.

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Questions from Ranking Member John Barrasso

Question 1: Last month, TerraPower and X-energy sent me a letter requesting legislative action to enhance the effectiveness of the Advanced Reactor Demonstration Program at the Department of Energy. Why are these changes needed?

Under current law, DOE has very limited ability to maintain the confidentiality of intellectual property developed in the course of a funding agreement. As we outlined in our letter, this law is found in the Energy Policy Act of 1992 (EPACT 1992), which affects DOE funding agreements, and in the Stevenson-Wydler Act, that more broadly covers certain federal agreements, and which is incorporated by reference in EPACT 1992. These statutes provide a maximum of only five years of confidential treatment for information that would ordinarily be subject to unlimited confidential/proprietary/trade secret information treatment if such information is developed in the course of a U.S. government funding agreement. After that, the U.S. Government can be required to release the information in response to Freedom of Information Act requests, and the information may be used by domestic and, and more importantly, by foreign competitors, including those in Russia and China.

Although, in many cases, a confidentiality period of five years may be sufficient to balance the desire for the public to benefit from government-funded research while providing time for the developer to commercialize its product, that simply is not the case with highly sophisticated nuclear technology, where development and implementation cycles are significantly longer than those of most other technologies. Congress recognized this when they provided a 7-year time frame to complete the ARDP demonstration projects.

This issue, which could allow advanced nuclear technology to be obtained by competitors prior to a demonstration project being completed, can put America's competitiveness in this market at risk. This issue can be easily fixed, however, by revising the law to allow DOE to have rational and reasonable flexibility to extend the maximum period of confidential protection to thirty years for areas like nuclear technology development. Such a change is consistent with the United States' interest in developing commercially viable advanced nuclear technologies to compete with Russian and Chinese designs.

Question 2: The Energy Act of 2020 authorized the Department of Energy to carry out a program to support the availability of high assay low enriched uranium (HALEU).

- a) Is the Department taking the necessary steps to establish this program and make HALEU available?
- b) Given sufficient resources, could the Department accelerate their efforts to meet your needs?
- c) Beyond downblending stockpiles of material held by the Department, I understand that Russia is the only other current source of HALEU. Will you have to consider contracting with Russia if the Department is unable to fulfil its obligation under the Energy Act of 2020?

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- d) Will you commit to acquiring HALEU from a supplier here in the United States, if such a supplier is available?

Like most advanced reactor designs, Natrium will need HALEU to fuel its reactor. As of today, there is not a domestic supplier of HALEU to meet the fuel needs of American demonstration projects or the subsequent commercial reactors. We are encouraged by the efforts of the Department to develop domestic HALEU production and to help developers secure access to the HALEU we will need to power our demonstration reactor as well as our subsequent commercial reactors.

As part of our ARDP proposal, we committed to invest in domestic HALEU production capabilities in partnership with Centrus. Our hope is that our investment, coupled with the demand from Natrium, X-Energy and other developers will help build domestic enrichment capacity in the United States. We think that proposals for a HALEU bank, in which the United States would contract to purchase HALEU over a period of years and then make that HALEU available for developers to purchase as needed, can help provide the HALEU we will need to power our reactors while providing market certainty to attract the capital necessary to build out domestic enrichment capabilities.

Having domestic enrichment capabilities will help ensure the reliable availability of HALEU at a reasonable price for the ARDP demonstration projects and for the domestic commercial market that will follow. We support efforts to develop such capabilities in the United States, and as noted, have invested directly to help catalyze the development of those capabilities. If, however, domestic capabilities are insufficient to meet our fuel needs we will have no choice but to look at foreign suppliers.

Question 3: Your company is developing other advanced nuclear technologies beyond the Natrium reactor. Will you describe those designs and how they will complement the Natrium reactor in the market?

In addition to Natrium, TerraPower is developing a Molten Chloride Fast Reactor (MCFR) technology. MCFR technology seeks to design a low-cost reactor that can operate safely in high-temperature regimes. The MCFR technology promises to do more than generate high efficiency electricity; it also offers potential in alternative industrial markets, such as process heat and thermal storage. As countries look to decarbonize their industrial sectors in addition to their electricity systems, tools like the MCFR can play a meaningful role in achieving those goals.

Southern Company was selected as Prime awardee, with TerraPower's MCFR technology, to develop the Molten Chloride Reactor Experiment (MCRE), along with the Department of Energy and INL, as part of the ARDP's Risk Reduction program. Over the next few years, Southern will build a small, fast spectrum salt reactor experiment to provide important data on the operation and design of next-generation molten salt reactors, and we look forward to working on this exciting project.

Question 4: TerraPower partnered with GE-Hitachi to develop the Natrium reactor. These same companies are contracted with the Department of Energy to support the Versatile Test Reactor. How does

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your work on the Advanced Reactor Demonstration Program and the Versatile Test Reactor complement each other?

There is significant potential for collaboration and learnings as we work on Natrium and the VTR. The VTR will be a pool type sodium fast reactor, designed with the participation of GE-Hitachi and TerraPower, and constructed by Bechtel. The Natrium demonstration reactor will be a 345MW pool type sodium fast reactor, designed by TerraPower and GE-Hitachi, and constructed by Bechtel. In addition to allowing one project to learn from the other, we can achieve savings by helping to build out the supply chain for materials and products that can work with both reactors, advancing U.S. leadership in advanced reactor innovation and deployment.

Question 5: In your written testimony, you discussed work with Oak Ridge National Laboratory to separate medical isotopes. Will you please elaborate on this work?

TerraPower's Targeted Alpha Therapy work produces medical radioisotopes to be used to develop new treatments for cancer. Radiation therapy has long been used to treat cancer, but targeted alpha therapy expands the kinds of cancers that can be treated by radiation by providing precise, low levels of radioisotope treatment.

Targeted Alpha Therapy works by combining radioisotopes with Monoclonal antibodies (mAb), which are laboratory-made proteins that find and attach to specific kinds of pathogens inside the body. The mAb deliver the radioisotope to the cancer cell allowing the associated radioisotope to destroy cancer cells while causing minimal damage to healthy cells surrounding the cancer. In addition to monoclonal antibodies, the pharmaceutical industry has developed multiple other promising delivery mechanisms for our radioisotopes. This provides treatment options for cancers that cannot be treated by surgery or by less precise forms of radiation therapy.

One alpha-emitting isotope, Actinium-225, shows particular promise for Targeted Alpha Therapy. Actinium-225 is a rare isotope, but TerraPower has developed technology to harvest the radioisotope from Thorium-229. Thorium-229 can be recovered from waste material currently housed at Oak Ridge National Laboratory. In partnership with Isotek Systems, TerraPower is working to convert this waste material into potentially groundbreaking treatments for cancers. In addition to the creation of new treatments, the project will also save taxpayers money. ORNL has estimated that this work will save taxpayers \$90 million.

Question 6: In your written testimony, you stated that Natrium will separate the “nuclear island” from the energy storage and electricity systems. How will this reduce costs?

In addition to using advanced coolants and fuels to improve the efficiency of our reactor, Natrium also introduces new thinking in overall plant design. The light water reactors currently deployed throughout the United States generate electricity much like any other form of thermal energy. The reactor creates heat, the heat is used to generate steam, and the steam spins a turbine that produces electricity. Because

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this all happens in the same regulated envelope that houses the nuclear reactor, all of these components must be constructed to nuclear safety standards.

Sodium is different. Instead of using our heat to generate steam, we will use the heat from Sodium to power a massive energy storage system. The energy storage system uses molten salt, which has been used successfully as an energy storage technology in concentrated solar plants around the world. Energy production will come from the molten salt storage system, rather than from steam generated directly from the reactor. The energy storage system does not contain nuclear material, and will be near, but not on, the nuclear island. As such, the non-nuclear parts of the plant can be built to general industrial safety standards. This will reduce the amount of nuclear grade construction necessary to build a fully operational plant.

It's also worth noting that the Sodium reactor itself is a simple, efficient design that can operate at atmospheric pressure. In addition, we use sodium as a coolant, which has a boiling point of well over 800 degrees Celsius. One of the primary cost drivers of conventional light water reactors is the need to account for the high pressure necessary to make water an effective coolant in a nuclear reactor. That pressure means that designs must account for accidents resulting in a rapid release of radioactive coolant. By avoiding high pressure, and making a simple design with an advanced coolant, we can also reduce cost within the nuclear island.

Question 7: What do you consider the greatest risks to the success of the Advanced Reactor Demonstration Program?

Congress correctly required the ARDP Demonstration projects to be completed in seven years, which will ensure that the technology can be commercially available as states are looking to meet decarbonization, pollution reduction, and reliability goals. Meeting this timeline will require a concerted effort by both the developers and the Department of Energy to work efficiently to avoid any unnecessary delays.

As is the case with any major construction project, the ARDP Demonstration projects will require funding on an "S-Curve," where the total cost will go up each year for most of the life of the project, before coming back down in the final years. Because this is a federally cost-shared project, that means that appropriations levels will need to increase to meet the federal cost share for each of the first number of years of the project. Unlike traditional R&D programs, flat funding as a result of a continuing resolution, or insufficient funding to meet costs shares, could cause delays that could put the schedule and budget in jeopardy.

As such, we encourage Congress to explore options to ensure the funding necessary to meet federal cost share requirements for the demonstration projects throughout the seven-year life of the program.

In addition, both of the ARDP demonstration reactors will require High Assay Low Enriched Uranium (HALEU) fuel. Today, the United States lack the capabilities to produce HALEU, which could make securing the fuel necessary to power our reactor difficult. Congress and the Department of Energy have examined a number of options to ensure the availability of HALEU, including a HALEU bank, in which

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the federal government would purchase and store HALEU over the next few years, and then resell that HALEU to developers to ensure availability of the fuel. TerraPower is investing directly in enrichment capability with Centrus, but we support ideas like the HALEU bank which could help ensure HALEU availability with little to no cost to taxpayers.

Question from Senator James E. Risch

Question: As the birthplace of nuclear energy, it is troubling that the United States has ceded much of its world leadership in nuclear to countries like Russia and China. If we are to reclaim this leadership, it is crucial that we act with urgency to demonstrate advanced reactors here in the U.S. Reactor development companies like TerraPower and X-Energy are leading the way to market. The Idaho National Lab is the nation's lead nuclear laboratory and home to the Nuclear Reactor Innovation Center (NRIC), which is helping to smooth the path for advanced reactor deployment. We've already demonstrated 52 reactors at INL, which is why there is no better place to demonstrate nuclear reactors than in Idaho.

It is my understanding that both of you engaged INL to support your technical scope of work. Can you share how the Idaho National Lab and the overall lab system has helped your companies prepare for the demonstration of your reactors?

Perhaps most importantly, Sodium has been designed based upon the decades of experience in sodium fast reactors through the construction and operation of Experimental Breeder Reactor I and Experimental Breeder Reactor II at Idaho National Laboratory (INL), as well as the Fast Flux Test Facility at the Hanford Site. Sodium would not exist without the decades of work to advance nuclear technology performed at INL and at the Hanford Site.

In addition, TerraPower has worked closely with INL on the development of our technologies. This has included significant work on the design of our fuel assemblies, as well as the development of the TREAT loop. INL has been a trusted and key partner for TerraPower throughout our 14-year history.

For Sodium, we will continue to work closely with INL as we seek to answer questions relating to fuel fabrication, fuel qualification, efforts to secure HALEU, methods development, testing of irradiated materials, and corrosion testing. We also anticipate a significant role for INL as part of Southern Company's Molten Chloride Reactor Experiment award, on which TerraPower is providing molten chloride salt engineering and design capability. We anticipate that INL will host the MCRE reactor in partnership with the National Reactor Innovation Center (NRIC) at INL.

In both of our ARDP projects, we anticipate a high level of engagement and partnership with INL.

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Questions from Senator Steve Daines

Question 1: Mr. Levesque, recycled or depleted uranium can now be used for the next generation of small nuclear reactors. What can we do to ensure access to recycled uranium?

Our Sodium design is based on learnings from our Traveling Wave Reactor technology, which is designed to run on depleted uranium, the waste product from uranium enrichment. As we further develop Sodium, we see the potential for larger reactors that can be powered by depleted uranium. The United States has approximately 800,000 metric tons of depleted uranium at former DOE enrichment sites.

The Sodium reactor we are currently working to build will be fueled by High Assay Low Enriched Uranium (HALEU). We look forward to working with the Committee and the Department of Energy to ensure the availability of HALEU for the ARDP demonstration reactors, and for the commercial reactors that will follow.

Question 2: Mr. Levesque, the Montana State Legislature is working on legislation to study placing advanced nuclear reactors at closed coal powered units where the infrastructure for energy generation and distribution already exists. How can your technology help create jobs in rural communities and will you commit to working with Montana as they proceed with their study?

Sites with retiring coal plants can be an excellent place to site new advanced reactors, as these sites have highly skilled and trained energy workforces, connections to the electricity grid, and many of the physical attributes like access to water that are required by many advanced nuclear plants. Advanced reactors can also provide firm power to the grid, replacing the firm capacity the grid will lose when these coal plants are retired. These plants can help create jobs in rural communities both through the thousands of highly skilled construction jobs needed to build the reactors, but also through the hundreds of well-paying permanent jobs needed to operate the plant. On average, jobs in nuclear tend to pay higher than jobs associated with any other energy source – including both fossil fuel and renewable energy.

TerraPower would be happy to help the state of Montana better understand advanced nuclear generally, and the Sodium technology specifically. Sodium will be demonstrated as a part of the Department of Energy's Advanced Reactor Demonstration Program, and we would be happy to have Montana learn more about the technology as we build it.

Question 3: Mr. Levesque, like 21st century mining practices, 21st century nuclear energy is much different than it was in the past. What is industry doing to engage with the American people on the safety standards, high-paying jobs, and community benefits of modern nuclear energy?

Most importantly, the advanced nuclear industry is developing technologies with step change improvements in safety, which both reduce the likelihood of severe accidents and reduce the cost to build and operate our reactors. The most important step we can take to convince the public of the benefits of the technology is to create safe, cost effective reactors that can provide low cost, abundant clean power as well as good paying jobs in the communities in which they are built.

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The economic impact for communities that host a nuclear power plant can be significant. As recent studies have shown, nuclear jobs pay more than any other in the energy sector and can provide significant economic opportunity for skilled workers and the communities in which they reside. Nuclear power tends to be most popular in the communities that host nuclear power plants, and for good reason.

To build that support, it's important that we directly engage with the public and with policymakers on the steps we are taking to achieve those goals. We need to listen to the concerns of all of the stakeholders in the communities in which we hope to operate, be open and transparent with our technology and our plans, and work to earn the public trust. We will do just this as we prepare to site the demonstration reactor under the ARDP award.

Questions from Senator Lisa Murkowski

Question 1: Congratulations on being selected by the DOE's Advanced Reactor Demonstration Program. The Energy Act of 2020 formally authorized the Program, which was part of the Nuclear Energy Leadership Act, and which has an ambitious timeline to demonstrate your designs. As you went through the ARDP process, what were some of the challenges and hurdles that you faced, or that you are aware other applicants faced, that you feel could be improved upon by DOE in order to better implement the future of the program and allow your companies to be successful?

We remain impressed with the thoughtfulness that Congress put into the design of the ARDP and are grateful for the Department of Energy for selecting two truly advanced designs. The structure of the program and the rightfully ambitious timeframe forced developers to rethink assumptions and build new partnerships. I will note that the ARDP does depend on consistent, regular appropriations to meet the federal cost share required to complete the projects. A failure by Congress to meet cost share requirements by failing to appropriate enough funds to cover costs share, by missing appropriations deadlines, or by relying on flat funding due to a continuing resolution does place the private capital put into the projects, and the timeline prescribed by Congress, at risk.

We have identified some statutory changes related to intellectual property that will be necessary to encourage the development of commercial advanced nuclear technologies through the ARDP. Under current law, intellectual property developed in conjunction with a DOE demonstration project is only protected from public disclosure for five years. As you noted, the seven-year timeline for demonstration of advanced nuclear technology is "ambitious." But under current law, the Department could be required to share intellectual property associated with advanced nuclear designs with competitors in places like Russia and China before we've even completed our demonstration reactor. We believe that extending the protection period to thirty years is more appropriate for technologies like advanced nuclear. Fixing this issue would give developers more confidence in partnering with DOE to demonstrate advanced nuclear technology.

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Question 2: What do you see as the biggest challenges to meeting the congressionally directed goals, milestones, and timelines of the ARDP?

Congress rightfully required the ARDP Demonstration projects to be completed in seven years, which will require a concerted effort by both the developers and the Department of Energy to work efficiently to avoid any unnecessary delays. As is the case with any major construction project, the ARDP Demonstration projects will require funding on an "S-Curve," where there the total cost will increase for the first number of years, before coming back down in the final years. Because this is a federally cost-shared project, that means that appropriations levels will need to increase to meet the federal cost share for each of the first number of years of the project. Unlike traditional R&D programs, flat funding as a result of a continuing resolution, or insufficient funding to meet costs shares, could cause delays that could put the schedule in jeopardy.

As such, we encourage Congress to explore options to ensure the funding necessary to meet federal cost share requirements for the demonstration projects throughout the seven-year life of the program.

In addition, both of the ARDP demonstration reactors will require High Assay Low Enriched Uranium (HALEU) fuel. Today, the United States lack the capabilities to produce HALEU, which could make securing the fuel necessary to power our reactor difficult. Congress and the Department of Energy have examined a number of options to ensure the availability of HALEU, including a HALEU bank, in which the federal government would purchase and store HALEU over the next few years, and then resell that HALEU to developers to ensure availability of the fuel. TerraPower is investing directly in enrichment capability with Centrus, but we support ideas like the HALEU bank which could help ensure HALEU availability with little to no cost to taxpayers.

Question 3: What are some of the areas in advanced reactor technology in which we can better focus research and technology investments?

We will continue to work with the Department of Energy on the development and qualification of fuels and fuel assemblies, and continued development of fuel technologies will benefit a broad range of reactor designs. This includes work to develop new sources of High Assay Low Enriched Uranium (HALEU), which will be necessary to power the next generation of advanced reactors.

Question 4: In addition to the Advanced Reactor Demonstration Program, TerraPower is working with GE Hitachi and the Department of Energy to develop the Versatile Test Reactor (VTR). This specialized fast research reactor can provide a capability we have lacked since the 1990s and is a critical part of the government's efforts to develop new nuclear technologies. While the Energy Act of 2020 authorized the Versatile Test Reactor, the project currently is not on track to be successful. The VTR will operate as an open-access user facility in the DOE national lab system, facilitating academic, public, and private research and could also support our allies. How important is the VTR to the global advanced nuclear industry?

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The Versatile Test Reactor can be a key part of America's advanced nuclear science infrastructure and can play a critical role in allowing American advanced nuclear technology developers to test materials and fuels in the fast neutron spectrum to build better fuels, improve existing fuels, and develop and test new materials.

Currently, the only available fast neutron test reactor available to American developers is the BOR-60 an over fifty-year-old research reactor in Russia. There are obvious competitiveness concerns about the only fast neutron test reactor available to American developers being based in a country seeking to dominate the advanced nuclear market. We support the development of the VTR and look forward to working with our partners GE-Hitachi and Bechtel to do make the VTR a reality.

Question 5: Why do you believe you can build Natrium through the ARDP without the VTR?

The United States has significant experience with Sodium Fast Reactors, through the construction and operation of the Fast Flux Test Facility (FFTF), and the Experimental Breeder Reactors I and II. In addition, TerraPower has conducted considerable fuels and materials testing at the BOR-60 reactor in Russia, in the 14 years we've spent designing next generation sodium fast reactors. In the future, having access to the VTR will enable us to improve our fuels, and it will undoubtedly be an important tool for future advanced nuclear designs. That said, we are confident we can complete our ARDP project without the VTR being completed.

Question 6: How can completing the ARDP and building your Natrium reactor help support the deployment of the VTR?

The VTR will be a pool type sodium fast reactor, designed by GE-Hitachi and TerraPower, and constructed by Bechtel. The Natrium demonstration reactor will be a 345MW pool type sodium fast reactor, designed by TerraPower and GE-Hitachi, and constructed by Bechtel. In addition to allowing one project to learn from the other, we can achieve savings by helping to build out the supply chain for materials and products that can work with both reactors.

Question 7: I'm sure that your company would like to build many more reactors after your demonstrations through the Advanced Reactor Demonstration Program (ARDP). While the ARDP is extremely important for this effort, I want to look at what else can be done to help incentivize widespread deployment. One part of my Nuclear Energy Leadership Act that was not included in the Energy Act of 2020 was related to long-term power purchase agreements at Federal facilities. Would power purchase agreements at federal facilities be useful as you look to continue to deploy your advanced reactor designs?

You are absolutely correct that we plan to build multiple, commercial scale reactors to help meet our country's need for clean, flexible, and firm power. We anticipate the majority of this demand to come from utilities. But as the federal government looks to procure energy from clean sources, technologies like Natrium can play a critical role in eliminating emissions while also providing reliable, consistent, flexible power to our military bases, VA hospitals, and other critical federal facilities.

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In addition, federal policies that recognize the value of always available carbon free energy will help advanced nuclear companies compete. Incentives, such as clean energy standards, clean energy tax credits, and market reforms that value contribution made by clean, firm, flexible power systems can help grow demand for advanced nuclear power.

Question 8: If Congress was to direct the Nuclear Regulatory Commission in conjunction with their work with the Department of Defense on mobile reactors to conduct a study on the best practices or recommendations to streamline the regulatory process for advanced reactor designs, what criteria should be considered for the study?

We are grateful for the work of Congress and the NRC to modernize the regulatory process and to evaluate the safety of advanced reactors based upon the safety cases presented by these new technologies. Ensuring that regulations are right sized for specific reactor designs and sizes is important for the future of the industry. The NRC has recognized this principle in its recent rulemaking on Emergency Planning Zones for smaller reactors, which present a completely different safety case than gigawatt size large light water reactors. As new reactors are designed with different sizes, coolants, safety systems, and fuels, regulations should be appropriately adjusted to recognize the technical differences of various reactors. For example, a passively cooled 1MW reactor presents a different safety case than a 1,000MW pressurized water reactor. Those differences should be accounted for in thinking about regulations.

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Questions from Ranking Member John Barrasso

Question 1: *Is the Department of Energy making sufficient progress toward establishment of the strategic uranium reserve? If not, why not?*

The Department of Energy (DOE) is not making sufficient progress towards establishing the Strategic Uranium Reserve (the “Reserve”) and the delays are deeply concerning to the member companies of the UPA who need to make investment and development decisions based on a timely implementation of this important policy. In December 2020, the Reserve was funded for FY2021 through bipartisan appropriations legislation, albeit at 50 percent of the DOE-requested and Nuclear Fuel Working Group-recommended amount of \$150 million. Accordingly, Congress directed DOE to establish the Reserve in FY2021 and begin buying mined U.S. origin uranium for the program. The UPA understands that DOE’s implementation of the Reserve has been delayed by the Presidential Administration transition. To date, President Biden has not nominated an Assistant Secretary for Nuclear Energy. This is a crucial position overseeing the Office of Nuclear Energy, which along with the National Nuclear Security Administration is responsible for administering the Reserve. The UPA is concerned that DOE may require a NEPA analysis to implement the Reserve. All production, conversion and storage facilities and activities that can meet the goals of the Reserve are licensed facilities. These facilities have undergone rigorous licensing processes including competition of all required environmental analysis. Establishing the criteria and contracting mechanisms for procuring uranium and conversion services for the Reserve is procedural in nature and, like other similar DOE programs, can comply with NEPA by relying on an established categorical exclusion. We encourage DOE to rely on these existing NEPA analyses rather than duplicate the effort and delay the program.

Question 2: *Some advanced reactor developers are calling for a high-assay, low-enriched uranium (HALEU) bank, or a strategic reserve of HALEU.*

a) How would such a bank impact your operations?

The growing realization of nuclear power’s important role in a lower-carbon, green-energy future is reassuring in terms of preserving and extending the existing fleet of nuclear reactors. But it is also very encouraging for the deployment of advanced and small modular reactors (SMRs). It is my understanding that the majority of the leading SMR technologies require a HALEU fuel cycle. Many of these innovative designs are supported by DOE’s Advanced Reactor Development Program. A robust domestic fuel cycle supporting these initiatives is vital in reestablishing American nuclear leadership, both here and abroad. In this regard, the UPA is supportive of efforts to revitalize American uranium, conversion, and enrichment capacity to support domestic HALEU production. Maximizing domestic uranium content in HALEU will not only allow the United States to address future “unobligated” uranium needs for defense programs (like Project Pele micro-reactors) but will also diminish our reliance on foreign fuel from countries like Russia and China. The U.S. is already over-dependent on these countries for other critical minerals; we should not make the same mistake and become over-dependent on foreign uranium for the next generation of nuclear power technologies. I speak for all the UPA member companies in saying that

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a U.S. policy commitment toward enhanced domestic HALEU capabilities would be an additional needed stimulus in our uranium production and development decisions.

b) Does it make sense to integrate this concept with the strategic uranium reserve, which Congress already directed the Department of Energy to establish?

It may make sense to integrate this concept with the Strategic Uranium Reserve but only if the reserve is expanded to accommodate this additional mandate. The current Strategic Uranium Reserve is intended to: (i) support domestic energy security for our commercial reactor fleet in times of supply disruption, and (ii) stimulate production of stockpiled, unobligated, U.S. origin uranium for future defense needs. Support of HALEU fuel security would be a third and, somewhat urgent, mandate as small modular and advanced reactors are slated for development and operations within this decade. I would assert that the annual \$150 million targeted spend is insufficient to support all three of these programs simultaneously, especially considering that FY2021 funding is only at the reduced \$75 million.

Question 3: *There is growing concern that the Department of Energy may not be able to supply the HALEU needed for the Advanced Reactor Demonstration Program.*

a) Is it possible to establish a supply of HALEU here in the United States in time to meet the needs of the Advanced Reactor Demonstration Program?

Absolutely. The uranium and conversion industries are prepared to immediately ramp up production to support this important initiative, provided they are given the requisite commercial incentive. The enrichment hurdle may be more challenging, but several potential solutions have been proposed. The UPA encourages U.S. policies that promote the greatest possible quantity of domestically produced uranium content. Taking the easy route and increasing imports of Russian or Chinese supplies will only exacerbate our over-reliance on those sources.

b) What actions should the U.S. take to ensure a reliable near-term source of HALEU for advanced reactors?

U.S. policy should continue to support the revitalization of the domestic uranium, conversion, and enrichment industries for all the reasons articulated by the witnesses testifying in this hearing. The uranium and conversion industries can respond quickly to the increased demands of the strategic stockpile and HALEU fuel, while the critical path would appear to be enrichment. Should the requirements of this HALEU fuel cycle advance more quickly than the deployment of these domestic enrichment alternatives, the UPA suggests borrowing blended-down HEU supplies from DOE inventories with the objective of replenishing those stocks from the reconstituted and revitalized domestic nuclear fuel cycle. This action would meet the immediate needs of the near term HALEU reactor growth, while preserving our strategic stocks of unobligated, U.S. origin enriched uranium.

c) What are the consequences if these companies have to go to Russia for their HALEU supply?

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The challenges of the past year have only reinforced the importance of domestic control of strategic infrastructure and supply chains, whether it is pharmaceuticals and respirators, or rare earth elements and critical minerals, like uranium. The American nuclear energy industry that supplies 20% of our electricity and over 50% of our carbon-free power is now completely reliant on foreign uranium supplies with 50% of those coming from Russia, Kazakhstan and Uzbekistan. As the Atlantic Council witness testified, this is not only bad domestic policy, but it also diminishes American nuclear competitiveness and geopolitical leadership abroad. Turning to Russia, or China, for HALEU fuel needs only makes a bad situation worse, especially when we have a pathway to American HALEU fuel independence.

Question 4: *For years, China has been rapidly increasing its uranium assets throughout the world, especially in Africa. To what extent do China's efforts to increase its uranium resources threaten uranium producers here in the United States?*

The Chinese Communist Party plays the long game in terms of coordinating its state-owned enterprises towards commercial and geopolitical goals. Nowhere is this more evident than in the Chinese nuclear sector. The Chinese state-owned uranium companies (subsidiaries of CNNC and CGN) are actively engaged in securing uranium supplies by taking direct ownership stakes in mines around the world. This is increasingly removing available supplies from western, free-markets, and putting them under Chinese control. In just the past few years, the uranium mining industry of the southwest African country of Namibia (a top five global uranium producer) has become almost completely controlled by Chinese state-owned entities through their ownership of the Husab and Rossing uranium operations. These actions by Chinese SOEs are also undercutting the market by bringing more uneconomical supply into an already oversupplied market.

These bold moves show little regard for market signals or the commercial considerations and financial restraints of free market companies. Chinese SOE activity is another reason for the United States to maintain and grow our own domestic uranium production capabilities to enhanced U.S. energy security and economic security and ensure our geopolitical challenges do not gain more leverage over the U.S. energy industry.

Questions from Senator Mike Lee

Question 1: *As you said, only 265 people are employed in the uranium industry, 83 percent less than in 2008. From an industry and infrastructure perspective, what will this shrinking workforce mean for a domestic uranium production rebound?*

As I testified in the hearing, the domestic uranium and conversion industry continues to possess the resources, technologies, and people required to mount a successful revitalization of these critical industries. In absence of timely U.S. policy support, however, we are dangerously close to losing this industrial base and missing the opportunity to transfer knowledge to a next generation of uranium miners. The average age of the technical leaders within our member companies is rather advanced and while we are doing our best to cultivate the younger members of our team to become those future leaders, we need

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to give them visibility towards development of new projects, or restart of existing operations. It is not too late to act, but that time is upon us.

Question 2: *If the domestic uranium industry continues to decline at the current rate, what do you believe the state of the industry will be when we run out of HEU?*

The amount of U.S. HEU inventories held in support of critical defense needs (Naval propulsion reactors, defense missions, and now DOD micro-reactors) is understandably of a classified nature. However, we understand these stockpiles to be finite and declining. Next generation aircraft carriers and submarines, with their substantial initial fuel loads, only accelerate the drawdown of inventories which have dated back to the 1950's. We understand that it was the Department of Defense that requested that uranium be included in the Department of the Interior's list of critical minerals in support of American strategic needs. We also know that our adversaries would delight in America's inability to fuel its own strategic defense needs.

The domestic industry is losing people. And the companies that own U.S. projects are finding it increasingly difficult to justify the significant costs of maintaining domestic uranium projects on standby, costing millions of dollars per year per project. It takes up to a decade or longer to license and construct new uranium projects in the U.S., in addition to tens or hundreds of millions of dollars. Moreover, we will have completely lost our domestic expertise. If we allow our current infrastructure to disappear, it is highly unlikely that we will be able to bring it back on a timely basis to supply our future HEU requirements. Again, it is not too early to re-establish these strategic stocks and time is of the essence for the industrial base.

Question 3: *Can you speak to the state of uranium production in allied countries?*

The out-sized presence and influence of state-owned entities in the uranium industry has not only impacted America's ability to produce uranium, but also that of free-market enterprises in allied nations like Canada and Australia which have experienced significant reductions in production in recent years. Currently, there is only one uranium mine operating in all of North America, Australian production is on the decline, Namibia resources are being bought by China, and new developments in Western countries are being deferred as a result of the depressed uranium price. The global free market for uranium is in steep decline due to the influence of state-owned entities, mainly in Russia, China, and their allies, that are not driven by free market principles but rather geopolitical or anti-competitive behaviors.

Question 4: *Would you agree that mineral access restrictions and the regulatory environment are contributing to the decrease in American uranium's market share?*

The UPA would agree that mineral access restrictions and over-reaching regulations inhibit the American uranium industry from reaching its full potential. This is ironic, as the modern American uranium mining industry has the highest standards of health, safety, and environment, and we are regulated by an array of federal and state agencies. We are a global example of best practices in this regard. Unfortunately, when regulations are more ideologically driven with layers of overlap and redundancy, without the cost/benefit

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analysis of all stakeholders involved, we push the mining of critical minerals to foreign countries who may not share our high standards.

Question 5: *During the 1950s and 1960s, the U.S. Atomic Energy Commission, procured uranium by overseeing and funding domestic uranium ore mining. I think the uranium industry today is sometimes unfairly lumped in with these early extraction efforts that left a lot of tailings around. Can you speak to advances in techniques and technology that allow us to safely extract these materials today?*

The achievements of the Manhattan Project and the subsequent Cold War weapons race was historic in nature but was not without environmental cost (like abandoned mines and unmanaged tailings). While today's UPA member companies were not involved in these activities, we are sympathetic to the challenges faced by affected stakeholders, including Native American tribes, and we urge the U.S. Government to live up to its clean-up obligations. Much of this work is fully funded and it is imperative that the U.S. government live up to its commitments to clean up these legacy sites.

1. Modern mining practices, whether they be in-situ recovery or conventional mining, bear no resemblance to those government activities in the 1950's and 1960's. Today's uranium mining industry is bound by an array of state and federal regulations. We are committed to best-practices and constant improvement and we develop, operate, and reclaim our mining activities to the highest 21st century global standards.
2. Our modern industry is also uniquely qualified to assist the U.S. government in its obligations to clean up and restore the land on the Navajo Nation and other western states. However, we need a viable and thriving commercial uranium industry to be able to provide such a role. Certain of our members have existing capabilities and facilities that can safely and economically accept, recycle, and manage much of the cleanup work today, while other cleanup proposals may require many years of permitting and tens or hundreds of millions of dollars to construct.

By way of example, we have eliminated the 1950's/60's problem of abandoned mines through the modern-day regulations governing mine decommissioning, reclamation, restoration, and ongoing monitoring long after production. Any uranium mining operation in the U.S. must have a full plan of decommissioning, reclamation, and restoration before a permit to develop and mine is issued. The costs of these future reclamation activities are fully funded (in advance) by cash or bonding maintained by each mining company in the states in which they operate. Also, the majority of planned production in the U.S. going forward will utilize the In-Situ-Recovery (ISR) method of uranium extraction which is a less intrusive technology that pumps oxidized uranium from sandstone orebodies without the need for open-pits, underground mines, or associated tailings facilities. Lower impact in this regard means more straightforward reclamation and decommissioning and a faster pathway to land restoration post-mining.

Question 6: *In terms of environmental safety, how do you believe that domestic extraction practices compare to practices in other countries?*

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The safety culture of the American mining industry (both human and environmental) is a guiding principle of all our UPA member companies. We also believe that high standards of health, safety and environment not only reside in our regulatory requirements, but also in the good and ethical business practices that ensure our social license to operate in our communities. Uranium production that is pushed offshore, especially in the state-owned sphere of influence, cannot be assured to be held to our higher standards.

Questions from Senator Steve Daines

Question 1: *Mr. Melbye, uranium imports are following the same pattern as rare earths, where foreign state-owned entities are controlling the supply chain. This poses serious national security concerns. How can we prevent uranium from following the same path as rare earth elements?*

In the name of globalization and international free markets, America unfortunately grew complacent with regards to supply chain risks for critical manufacturing and minerals. This trend has been further compounded by government policy in the U.S. that has created significant regulatory hurdles that have retarded advancement of domestic mining of uranium and other critical minerals. Some things are simply too strategically important to be outsourced to state-owned enterprises in adversarial countries. Uranium is one such critical mineral, however, it is not too late to reverse the trend in our industry. According to the U.S. Geological Survey, the U.S. possesses over one billion pounds of uranium resources in known and likely deposits in various western states. A core of U.S. companies is ready and willing to take on this energy independence challenge with the right signals and policies from the U.S. Government. These companies invested heavily in permitting and constructing uranium mines that provide production capacity that meets 50% of America's needs that is ready to go, today. Limitations on imports or Russian uranium (as was achieved by the U.S. Commerce Department with support from Congress last year) and the establishment of the Strategic Uranium Reserve were great first steps in this revitalization process. It is important, however, to carry through on the quick implementation of the strategic reserve in FY2021 and its continued funding at a minimum of the recommended \$150 million level in FY2022 onward.

Question 2: *Mr. Melbye, like 21st century mining practices, 21st century nuclear energy is much different than it was in the past. What is industry doing to engage with the American people on the safety standards, high-paying jobs, and community benefits of modern nuclear energy?*

To truly measure the impact of nuclear energy facilities on local communities, we need only see what happens when existing plants are shutdown in terms of reduced tax base, employment, related economic benefits and of course the loss of massive amounts of safe, highly reliable, carbon-free, clean energy. As an industry, we have perhaps failed in communicating this effectively and letting the anti-nuclear rhetoric go unchecked. In a lower-carbon world where safe and reliable clean energy is valued, the nuclear energy industry has an incredible opportunity to make its case to a world that will require enormous amounts of electricity, not less, to power our modern economy. The widespread and rapid adoption of electric vehicles adds significantly to this challenge. While the existing fleet of reactors can boast safety achievements equal to that of wind and solar, especially in terms of kilowatts generated, the next

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generation of small modular and advanced reactors, can build on this enviable record with smaller footprints, unparalleled energy density and passive safety systems. We also must consider the high paying jobs these innovative clean-energy systems will bring to cities and regions, especially those impacted by job losses from other energy transitions.

Question from Senator Lisa Murkowski

Question: *While Alaska may be known for its oil and gas development, we also have abundant mineral resources, including graphite, platinum, and rare earth elements. Microreactor technology has the potential to reach remote mineral deposits that would otherwise not be economically viable to access and develop. Are mineral development and extraction an industry that microreactors could support, and what technologies could help the mining industry in the short and long-term?*

Small modular and micro-reactor technologies are ideally suited to support the development of mineral resources in remote locations. This is due not only to the high cost and logistical challenges of electricity sourced from diesel-fired generation, but also due to the significant Environmental and Social Governance (ESG) trend towards lowering/eliminating carbon emissions at the global operations of many of the world's leading mining companies. For example, Denver-based gold producer, Newmont Corporation, has committed to a 30% reduction in carbon emissions from its operations by 2030, with a complete elimination by 2050. While aspirational to some degree, these are very real commitments to not only make an impact on the environment, but also to appeal to institutional and retail investors who are demanding more in terms of environmental leadership. Black Rock Chairman, Larry Fink, articulated this clearly in his company's commitment to invest in companies subscribing to this net-zero commitment by 2050. For the energy-intensive mining industry, this is no easy task as uninterruptable power will be impossible to achieve using renewables alone. Fortunately, work on micro-reactors for mining applications is being advanced by the Canadian Government at the Chalk River Laboratories in conjunction with Ontario Power Generation. Several SMR designers are also engaged in discussion with mining companies to advance concept to reality. The astronomically high cost of electricity at remote mines, largely due to the logistical challenge of diesel oil transportation, often on seasonally available ice roads, presents an appealing competitive advantage for SMR's, not the least of which is reliability and lower cost of generation. While not surprising that Canada, with its extensive resource development tradition, is taking a leading role in this clean energy for mining trend, it sounds like something our U.S. universities and national laboratories (like Argonne and Idaho) could be working on in conjunction with industry to advance American contributions to these clean-energy, mining applications.

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Questions from Ranking Member John Barrasso

Question 1: In your written testimony, you referenced China’s “Belt and Road” initiative. Will you please describe this initiative and elaborate on what it means for U.S. global competitiveness in nuclear energy?

China introduced its Belt and Road Initiative (“BRI”) in 2013. Through the BRI, China initially sought to connect to the rest of Asia, as well as Africa and Europe, via land and maritime networks with the aim of spurring economic growth through interconnectivity. However, since its inception, BRI has now spanned to all regions of the world.¹ The BRI is the largest ever global infrastructure undertaking—far surpassing the United States’ Marshall Plan, which sought to rebuild Western Europe following the devastation of World War II—and just who will share in the benefits of its investment remains to be seen).

Under the BRI, Chinese banks and companies have provided billions of dollars for funding to build roads, power plants, railways, ports, and telecommunications infrastructure in dozens of countries.² The objectives of BRI focus on establishing and building linkages between China and the rest of the world in the following five areas: (1) enhanced policy coordination; (2) improved infrastructure connectivity; (3) reinforced trade and investment cooperation; (4) financial integration; and (5) supporting people-to-people collaboration.³

But the BRI efforts are not without consequences to both the host country and the United States. A Council on Foreign Relations Task Force (“CFR Task Force”) recently released a report, *China’s Belt and Road, Implications for the United States*, finding “that BRI worryingly adds to countries’ debt burdens, locks countries into carbon-intensive futures, tilts the playing field in major markets toward Chinese companies, and draws countries into tighter economic and political relationships with Beijing.”⁴ The CFR Task Force concludes that “the risks for both the United States and host countries raised by BRI’s implementation considerably outweigh its benefits,”⁵ and summarizes the concerning aspects of China’s BRI to include the following:

¹ Council on Foreign Relations, *Independent Task Force Report No. 79, China’s Belt and Road, Implications for the United States*, updated Mar. 2021 [hereinafter CFR Task Force Report], available at <https://www.cfr.org/report/chinas-belt-and-road-implications-for-the-united-states/>; (explaining, “Though principally aimed at developing countries, with Pakistan, Malaysia, Bangladesh, Myanmar, and Sri Lanka among the largest recipients of BRI funds, BRI also includes developed countries, with numerous U.S. allies participating.”); Organization for Economic and Cooperation and Development (OECD) Business and Finance Outlook 2018, *China’s Belt and Road Initiative in the Global Trade, Investment and Finance Landscape*, available at <https://www.oecd.org/finance/Chinas-Belt-and-Road-Initiative-in-the-global-trade-investment-and-finance-landscape.pdf>.

² CFR Task Force Report, *supra* 1, at vi.

³ United Nations Economic and Social Commission for Asia and the Pacific, *A Study of ICT Connectivity for the Belt and Road Initiative (BRI): Enhancing the Collaboration in China-Central Asia Corridor* (Sept. 2017), at 12 available at <https://www.unescap.org/sites/default/files/BRI.pdf>.

⁴ *Id.* at vii.

⁵ *Id.*

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- Undermining global macroeconomic stability and increasing the likelihood that debt crises will materialize over the coming years, by largely eschewing debt sustainability analyses and funding economically questionable projects in heavily indebted countries;
- Subsidizing privileged market entry for state-owned and non-market oriented Chinese companies;
- Enabling China to lock countries in to Chinese ecosystems by pressing its technology and preferred technical standards on BRI recipients;
- Ensuring countries' dependence on carbon-intensive power for decades through its export of coal-fired power plants, making climate change mitigation significantly more difficult;
- Making it harder for the World Bank and other traditional lenders to insist on high standards by offering quick and easy infrastructure packages that forego rigorous environmental- and social-impact assessments, ignoring project management best practices and tolerating corruption; and
- Leaving countries more susceptible to Chinese political pressure while giving China a greater ability to project its power more widely.⁶

The goal of the BRI is to connect the Chinese economy with the rest of the world. As a result, instead of looking West to the United States for trade and relationships, countries would instead look East to China. This undermines U.S. interests on multiple fronts, as noted in my written testimony, and it displaces U.S. companies, economic interests, as well as geopolitical interests in the host country.⁷

While the name may give the impression that most of the funding of the BRI is in roads and bridges, the biggest Chinese spending under the BRI—an estimated two-thirds—has actually been in *energy*, because of China's excess capacity in these areas and demand from BRI countries.⁸ With the help of Chinese state financing, China has connected its grid to the neighboring countries of Laos, Mongolia, Myanmar, and Russia, while investing in grid operations in Brazil, Italy, the Philippines, and Portugal. It has also built a number of power plants, including coal, renewable, and nuclear power plants throughout Southeast Asia and Africa, in addition to energy facilities in Europe and Latin America.⁹

China's BRI is what the United States faces when it competes for foreign nuclear projects abroad. As explained in my written testimony, China pursues these projects with the backing of state financing and with the full power of the Chinese government behind them. With this support, China is building or plans to build nuclear power plants in Asia, Europe, South America, and Africa—many as part of the BRI¹⁰—as

⁶ *Id.* at 3-4.

⁷ *See also id.* at viii.

⁸ *Id.* at 56.

⁹ *Id.* at 67.

¹⁰ Reuters, *China Could Build 30 'Best and Road' Nuclear Reactors by 2030: Official* (June 20, 2019), available at <https://www.reuters.com/article/us-china-nuclearpower/china-could-build-30-belt-and-road-nuclear-reactors-by-2030-official-idUSKCN1TL0HZ>.

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well as floating reactors for potential deployment in the contested South China Sea.¹¹ Russia is undertaking a similar effort with respect to exporting nuclear power plants for economic as well as geopolitical purposes, and the two countries are expected to dominate the multi-billion dollar global market for nuclear power plant construction into the foreseeable future.

Question 2: You discussed China's predatory lending behavior with its nuclear export deals. You mentioned issues associated with potential foreclosures of nuclear power plants in Africa. Will you elaborate on this issue?

To note, the discussion about China's lending behavior during my testimony was not specific to nuclear export deals, nor was it specific to potential foreclosures of nuclear power plants in Africa as China has not built any such plants to date (although it plans to). Rather, my testimony was a discussion on the uneven negotiating positions that can arise with host countries and the additional leverage the Chinese hold to support their interests when they develop energy projects in developing nations.

As previously noted, two-thirds of China's BRI spend has been on energy projects, and the rest has been spent largely on other types of infrastructure projects. When the Chinese government finances these projects, and the host recipient is unable to repay the debt, the Chinese may be able to take control over the host country's critical infrastructure assets. For example, in 2017, when Sri Lanka could not pay the debts it owed to Chinese companies for infrastructure projects, it was forced to sign over control of the major port of Hambantota to Beijing—given Beijing an ideal base of naval operations just a few mile south of its biggest regional rival India.¹² According to a former Sri Lankan foreign secretary, China made clear during negotiations concerning the Hambantota port that intelligence sharing would be a part of the deal too.¹³ And while actual asset seizure may be unusual, the risk is still clear that if a host country is unable to repay its debts to China, China would yield a powerful hook and the host country could end up yielding to China in other manners, including on political or strategic matters.

My testimony focused on the risks associated when a host country is billions of dollars in debt to China for something critical to the economic and political stability of their country—like electricity generation—and unable to repay the debt. Nuclear power plant projects are multi-billion dollar projects, and China is offered very favorable financing terms. For example, China is estimated to have financed 82% of its nuclear power plant projects in Pakistan (or around an estimated \$8 billion in financing) and it also plans to finance 85% of the cost of a two proposed reactor projects in Argentina (or around an estimated \$11 billion).¹⁴ The costs are these projects are high, elevating the risks associated with default.

¹¹ The Diplomat, *China's Risky Plan for Floating Nuclear Power Plants In The South China Sea* (May 10, 2018), available at <https://thediplomat.com/2018/05/chinas-risky-plan-for-floating-nuclear-power-plants-in-the-south-china-sea/>.

¹² New York Times, *Sri Lanka, Struggling With Debt, Hands a Major Port to China*, available at <https://www.nytimes.com/2017/12/12/world/asia/sri-lanka-china-port.html>.

¹³ CFR Task Force Report, *supra* 1, at 63.

¹⁴ World Nuclear Association, *Nuclear Power in China*, table "Export sales and prospects for Chinese nuclear power plants" (updated Apr. 2021), available at <https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx>.

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As noted in both my testimony as well as in the recent CFR Task Force report, “China’s supply of energy technologies and its push for global energy interconnection give it potential control over vital infrastructure in BRI countries.”¹⁵ The Atlantic Council has also released a recent report addressing how the U.S. can compete against China’s BRI efforts that further discusses China’s predatory behavior. The report explains “[c]oercive foreign aid, debt traps, and a lack of transparency” are common characteristics where China has invested heavily in infrastructure projects.”¹⁶

As China looks to build nuclear power plants across the world, including in a number of developing countries, what could happen should the host-country default, including the additional influence that China could yield, should be considered.

Question 3: In your written testimony, you describe a partnership between Russia and Egypt that went beyond a contract for nuclear power plants and includes a military relationship.

a) What risks do such partnerships pose to U.S. national security interests?

Nuclear exports create a 100+ year relationship with the host country (construction, operations, and decommissioning of a nuclear power plant project last about 100 years or more).¹⁷ By Russia and China being involved in nuclear projects around the world instead of the U.S., especially on critical infrastructure projects, then not only is the U.S. *not further developing* its relationship with the host country, but it is Russia and China *who takes our place*.

Unlike the U.S., where economic and national security conversations tend to be separate, China and Russia do not operate in this manner and their economic and national security conversations take a more integrated view toward what is in their respective country’s best interests. We see that in the Russia/Egypt example noted, but China’s BRI is a good example of where this is also occurring—where BRI serves the dual purpose of helping both China’s economic and geostrategic influence across the globe. And conversely, by promoting China’s economic and geostrategic influence, it undermines our own. In explaining that a number of BRI initiatives involve U.S. allies, the CFR Task Force explains: “If these U.S. allies were to turn to China’s BRI to build critical infrastructure, such as power grids, ports, or telecommunications networks, it could complicate U.S. contingency planning and make coming to the defense of its allies more difficult.”¹⁸ And over the long term, countries may even cease to be our allies if their economies become fundamentally intertwined with China’s and Russia’s.

¹⁵ *Id.* at 67.

¹⁶ Atlantic Council Report, *Global Strategy 2021: An Allied Strategy for China* at 21, lead authors Matthew Kroenig and Jeffrey Cimmino, available at <https://www.atlanticcouncil.org/wp-content/uploads/2020/12/Global-Strategy-2021-An-Allied-Strategy-for-China.pdf>.

¹⁷ Center for Strategic & International Studies, Michael Wallace, Amy Roma, and Sachin Desai, *Back from the Brink: A Threatened Nuclear Energy Industry Compromises National Security* (July 2018) available at https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/180714_Wallace_BackFromtheBrink_Web.pdf.

¹⁸ CFR Task Force Report, *supra* 1, at 14.

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b) How can the United States provide developing countries, which seek nuclear energy for civilian and peaceful purposes, an alternative to Russian or Chinese partnerships?

The first and most important way to provide developing countries an alternative to Russia or China is by being able to offer a reactor design that they want to buy—size, price, and technology type all go into this consideration here. The Department of Energy’s Advanced Reactor Demonstration Project, which is aimed at supporting the construction of two advanced reactor designs to provide power to the grid by 2027, and a number of other designs after that, should go a long way in this regard.

Second, the U.S. should use all the tools at its disposal to offer a competitive package against Russia and China, including coordinating with U.S. nuclear industry, ensuring financing tools are available through the Export-Import Bank of the United States and the U.S. International Development Finance Corporation, and encouraging institutions like the World Bank to do the same. This should be part of a “whole of government” approach to supporting these efforts, including through the State Department, the U.S. Department of Energy, the U.S. Trade Representative and within the White House. Other activities could include: ensuring that key U.S. government initiatives to support projects in developing countries include nuclear (such as for climate change efforts);¹⁹ streamlining the negotiation process for Bilateral Agreements for Nuclear Cooperation; providing assistance for countries looking at standing up new nuclear regulators (e.g., something employed with great success in the United Arab Emirates, and which could be run through the U.S. Nuclear Regulatory Commission), and thinking creatively about ways to offer additional support (e.g., through jobs training programs). These would all situate the U.S. in a better position than it is today.

c) Would credible nuclear partnership offers from the United States give developing countries more leverage if and when they chose to negotiate with Russia and/or China?

Yes, more options, especially from a country like the U.S., would provide more leverage for the host country.

Question 4: In your written testimony, you mention opportunities for nuclear energy to contribute to the mission of the National Aeronautics and Space Administration (NASA).

a) Will you please elaborate on how nuclear technology and the Department of Energy have already contributed to NASA’s mission?

The U.S. Department of Energy (DOE) has long supported NASA. Most recently, there are two nuclear propulsion systems that NASA is exploring. First, is a nuclear electric system, which is highly efficient and allows a spacecraft to travel for longer periods although at lower thrust. The second type of system is a nuclear thermal propulsion, which is a high thrust system but still far more efficient than a

¹⁹ See Hogan Lovells Client Alert, *White House Climate Summit and Its Implications Around the Globe*, (April 27, 2021) available at <https://ehoganlovells.com/rv/f00786133bcea558a883a0b7d4da87c14991d10>.

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traditional rocket.²⁰ To this end, DOE recently published a solicitation for Nuclear Thermal Propulsion Reactor Interim Design seeking preliminary nuclear propulsion design concepts.²¹ NASA is also looking into fusion space propulsion technology, and participated in a very recent workshop with DOE's Advanced Research Projects Agency-Energy (ARPA-E) and the Defense Advanced Research Projects Agency (DARPA) on the near-term use of fusion propulsion systems for space travel.

However, as stated above, the DOE-NASA cooperation is not new. For decades DOE has managed plutonium-238 radioisotope thermal power generator production that is used in deep space probes.²² Additionally in 2018, NASA and DOE's National Nuclear Security Administration demonstrated the Kilopower Reactor Using Stirling Technology experiment, which uses a lightweight fission power system intended to allow for longer visits to the moon, and even Mars. Now, DOE and NASA hope to demonstrate a fission surface power system on the moon by the end of the decade.²³ DOE recently published a draft Request for Proposal²⁴ to solicit feedback from the nuclear and space industries to develop technologies for a fission surface power system intended to operate on the moon.

Additionally, toward the end of the previous administration, former Secretary of Energy Dan Brouillette and former NASA Administrator Jim Bridenstine signed a memorandum of understanding (MOU) to expand the DOE-NASA partnership on space exploration.²⁵ Space nuclear power and propulsion was among the key areas of interest listed in the MOU.

These are just a few examples of how DOE and NASA have partnered to enhance space travel through the use of nuclear technology.

b) How can nuclear energy contribute to future NASA missions, especially as it relates to the Moon and Mars?

There is a new space race developing—one in which the goal is much more ambitious than just going back to the Moon. China and Russia are moving forward on a lunar base,²⁶ and China claims it will

²⁰ NASA, *Nuclear Propulsion Could Help Get Humans to Mars Faster* (Feb. 12, 2021), available at <https://www.nasa.gov/directorates/spacetech/nuclear-propulsion-could-help-get-humans-to-mars-faster>.

²¹ *Nuclear Thermal Propulsion (NTP) Reactor Interim Design*, available at <https://beta.sam.gov/opp/ede625f6657e4802a4f5ea2e11b0074d/view>.

²² DOE, *Space and Defense Power Systems*, available at <https://www.energy.gov/ne/nuclear-reactor-technologies/space-power-systems>.

²³ DOE, *5 Things You Need to Know about Fission Surface Power Systems* (Aug. 20, 2020), available at <https://www.energy.gov/ne/articles/5-things-you-need-know-about-fission-surface-power-systems>.

²⁴ *Battelle Energy Alliance, LLC Request For Proposal No. TBD*, <https://beta.sam.gov/opp/falc351cb4724280b7ca7f0c9a8cf19c/view>.

²⁵ *Memorandum of Understanding Between National Aeronautics and Space Administration and U.S. Department of Energy Regarding Energy-Related Civil Space Activities*, available at https://www.nasa.gov/sites/default/files/atoms/files/nasa_doe_mou_energy_related_space_activities.pdf.

²⁶ Bloomberg, *China and Russia are Teaming Up in the New Space Race* (Apr. 12, 2021), available at <https://www.bloomberg.com/opinion/articles/2021-04-12/china-and-russia-are-teaming-up-in-the-new-space-race>.

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be the first to colonize Mars and even mine asteroids (which have immense natural resources).²⁷ To put it simply—nuclear fission and fusion technologies are the *only way* to achieve these goals and claim victory in this new race.

Chemical-propelled rockets, while essential for getting into Earth orbit, do not have the fuel efficiency or other features necessary to take anything other than small payloads infrequently to Mars. Reliance on chemical rockets alone is also very challenging for even developing and maintaining a Moon base. Nuclear fission or fusion power is also the only viable method of providing sustainable, significant power for any Moon or Mars base. Their essential nature in the new space race (called by some the “Deep Space Race”) is one reason why China is making increasingly heavy investments into nuclear and related advanced propulsion technologies, investments that reportedly dwarf current U.S. efforts.

As discussed in the response to Question 4(a), fission is being explored for space applications by NASA today, and there is incredible hope for the use of fission technologies in the near term. However, fusion is also being explored and likewise shows incredible potential. As previously mentioned, ARPA-E, DARPA, and NASA held a joint workshop on the application of fusion for space propulsion to meet scientific and national security goals. As just one example, the Direct Fusion Drive (DFD) is a conceptual design for deep space propulsion using a rocket engine powered by fusion, that if successful, could make travel to the moon and Mars very fast, and even get us to Saturn in as little as two years.²⁸ That is just one of *many* fusion and fission propulsion concepts currently under development by the private sector.²⁹

c) What else should the Department of Energy do to contribute to NASA’s missions?

DOE first and foremost needs to work with NASA to fund demonstration of novel space propulsion concepts based on nuclear fission and fusion. Although both agencies have taken steps in this direction—such as through the Kilopower program discussed above—there is much more that can be done. In particular, there are a host of private sector companies (mostly small ventures) pursuing novel and game-changing nuclear space propulsion concepts, but with no significant funding program to support their commercialization despite their importance to U.S. national security and the public benefit.³⁰ An ARPA-like program (such as an “ARPA-S”) in which DOE and NASA work together to support and help commercialize these novel nuclear fission and fusion propulsion technologies can have a tremendous impact on whether the U.S. will win the next space race. This makes it among the most important things DOE—with Congress’s support—can do to contribute to NASA’s mission.

²⁷ South China Morning Post, *China’s Nuclear Spaceships Will Be ‘Mining Asteroids and Flying Tourists’ As It Aims To Overtake US In Space Race* (Nov. 17, 2017), available at <https://www.scmp.com/news/china/policies-politics/article/2120425/chinas-nuclear-spaceships-will-be-mining-asteroids>.

²⁸ *Space, Fusion-Powered Spacecraft Could Be Just a Decade Away* (June 12, 2019), available at <https://www.space.com/fusion-powered-spacecraft-could-launch-2028.html>.

²⁹ Example private sector companies exploring novel space nuclear propulsion (fission and fusion) concepts include BWXT, Blue Origin, Lockheed Martin, General Atomics, Princeton Satellite Systems, Helicity Space, HyperJet Fusion Corporation, Starflight, and there are many more.

³⁰ *Id.*

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Thereafter, DOE and NASA can continue to build on recent steps taken to strengthen their relationship (including recent execution of a memorandum of understanding on space matters³¹) by laying out a path forward for novel nuclear propulsion technologies to be tested and eventually flown. Access to testing facilities and clarity as to the regulatory path forward for launch and testing will be critical. Down the line, something similar to a NASA COTS program (although at less cost) that helped SpaceX develop to eventually dominate the global rocket launch market could create a viable path forward for next-generation nuclear space propulsion technologies to be flown within a decade. Such a program will have a role for both NASA (as the end customer) and DOE (as the technical expert on nuclear issues).

Question 5: In addition to encouraging the development of advanced nuclear reactors, what else must the U.S. do to better compete with Russia and China?

As a general matter, the U.S. needs to be more strategic, proactive, and coordinated in how it competes with Russia and China globally. To compete, the U.S. must establish a holistic approach with both energy and economic initiatives, and form better partnerships with the private sector. This would also enhance the U.S. ability to offer a coordinated, “one-stop” package worldwide. As noted during my testimony, the U.S. can come back from the sidelines, but it will not happen without strong, collective, and consistent U.S. government support. As demonstrated in the aerospace market, when U.S. technology is supported, it can rise above its global competitors. In 2013, Russia controlled about half of the launch industry,³² but now, because of the success of Space X, Russia only holds 10% of the aerospace market.

This is important beyond just reactor development. It is estimated that over the next decade, the international market for nuclear equipment and services will be as high as \$740 billion. Moreover, every \$1 billion of exports by the U.S. could support as many as 10,000 jobs domestically.³³ Forming a collaborative working relationship with the commercial market will help the U.S. bolster its own economy and present a strong package worldwide.

As noted in a previous response, the first and most important way to provide developing countries an alternative to Russia or China is by being able to offer a reactor design that they want to buy—size, price, and technology type all go into this consideration. The Department of Energy’s Advanced Reactor Demonstration Project, which is aimed at supporting the construction of two advanced reactor designs to provide power to the grid by 2027, and a number of others after that, should go a long way in this regard. But there is also so much more that the U.S. can do.

After that, the U.S. should use all the tools at its disposal to offer a competitive package against Russia and China, including coordinating with U.S. nuclear industry, ensuring financing tools are available through the Export-Import Bank of the United States and the U.S. International Development Finance Corporation (and encouraging institutions like the World Bank to do the same), and offering a “whole of

³¹ *Memorandum of Understanding Between National Aeronautics and Space Administration and U.S. Department of Energy Regarding Energy-Related Civil Space Activities* (Oct. 19, 2020), available at https://www.nasa.gov/sites/default/files/atoms/files/nasa_doe_mou_energy_related_space_activities.pdf

³² *Ars Technica, Russia appears to have surrendered to SpaceX in the global launch market* (Apr. 18, 2018), available at <https://arstechnica.com/science/2018/04/russia-appears-to-have-surrendered-to-spacex-in-the-global-launch-market/>.

³³ Nuclear Energy Institute, *Nuclear Exports & Trade Overview*, available at <https://www.nei.org/advocacy/compete-globally>.

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government” approach to support these efforts, including through the State Department, the Department of Energy, the U.S. Trade Representative and within the White House. Other activities could be include: ensuring that key U.S. government initiatives to support projects in developing countries include nuclear (such as for climate change efforts);³⁴ streamlining the negotiation process for Bilateral Agreements for Nuclear Cooperation; providing assistance for countries looking at standing up new nuclear regulators (e.g., under programs run through the U.S. Nuclear Regulatory Commission), and thinking creatively about ways to offer additional support, (e.g., through jobs training programs). These efforts would all situate the U.S. in a better position than it is today.

Question 6: Recent changes to the Development Finance Corporation lifted the ban on financing of nuclear energy projects. I recently introduced the “Combating Global Poverty Through Energy Development Act” to support the financing of affordable and reliable energy projects, including nuclear energy.

a) What impact will these policy changes have on nuclear project financing?

These policy changes are very helpful and a necessary step to open the door to financing options for nuclear projects. Without them, the U.S. will not be able to offer an alternative to the state-backed and financed projects that Russia and China offer.

b) What else is needed?

Following the U.S. International Development Finance Corporation lead, the U.S. should pressure the World Bank to also lift its ban on financing of new nuclear projects, and encourage our allies to also remove any similar restrictions they have in their own Development Finance Banks. This is of particular importance, since “when an organization such as OPIC or the World Bank is involved in other kinds of projects, it can help aggregate additional financing for the deal.”³⁵

Question 7: Tomorrow’s advanced nuclear reactors will be smaller, safer, and more efficient. What opportunities do these characteristics present for the siting and economic viability of these reactors in the United States and throughout the world?

The U.S. is spearheading several dozen domestic ventures in next-generation nuclear technologies that boast a variety of attractive features for siting in the U.S. and around the world.³⁶ Nearly all advanced

³⁴ See Hogan Lovells Client Alert, *White House Climate Summit and Its Implications Around the Globe*, (April 27, 2021) available at <https://ehoganlovells.com/rv/f00786133beea558a883a0b7d4da87c14991d10>.

³⁵ Morning Consult, *Nuclear Industry Renews Pressure on OPIC to Allow Financing for Foreign Projects* at 27, (March 2019) available at <https://morningconsult.com/2019/03/01/nuclear-industry-renews-pressure-opic-allow-financing-foreign-projects/>.

³⁶ Third Way, *Mapping the Global Market for Advanced Nuclear* (Sept. 22, 2020), available at <https://www.thirdway.org/memo/mapping-the-global-market-for-advanced-nuclear>. Third Way has been tracking advanced reactor develops for several years now and their data shows an increased tick in participants each year. See, e.g., Third Way, *Keeping Up with the Advanced Nuclear Industry* (Jan. 2018), available at <https://www.thirdway.org/graphic/keeping-up-with-the-advanced-nuclear-industry>. This number shows a marked increase from the previous year, so the advanced reactor field is

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reactor technologies provide enhanced safety systems (e.g., passive safety features), below ground construction, flexible designs to fit customer needs to scale, and the ability to provide process heat. Process heat can be used in decarbonization of the industrial sector and to support other innovative technologies (e.g., hydrogen production, water desalination, and space propulsion/power and shipping).³⁷

These characteristics offer flexibility and less capital cost up front. While nuclear is capital intensive on the front end, the technology lasts for decades so the levelized cost of energy is ultimately less. Advanced reactors do not require as much staffing, security, and emergency planning based on the nature of the design as many are being buried underground and are smaller in size.³⁸ Additionally, with a much lower risk of accidental release, the emergency planning boundaries (known as emergency planning zones or EPZs) for a plant could be significantly reduced.³⁹ These features in particular are more attractive to remote communities and areas with lower grid needs, and has been demonstrated by projects at U.S. Department of Defense operating bases.⁴⁰

Questions from Senator James E. Risch

Questions: Your testimony details the national security challenges that exist when the United States is not in the lead on nuclear energy. How important is the success of the Advanced Reactor Demonstration Program to regaining American competitiveness in this sector? What policy proposals should congress consider that will allow U.S. nuclear companies to compete with state-owned nuclear countries like China and Russia?

As previously noted, the first and most important way to provide developing countries an alternative to Russia or China is by being able to offer a reactor design that they want to buy. Demonstration is *critical* to gaining acceptance globally. Few developing countries want to be the testbed for a new reactor design, from both a safety and cost perspective. The Department of Energy's Advanced Reactor Demonstration Project (ARDP), which is aimed at supporting the construction of two advanced reactor designs to provide power to the grid by 2027, and a number of other designs after that after that, is thus essential to success for the U.S. nuclear industry. Actual demonstration of a U.S. advanced reactor design in the United States through ARDP—which awardees are on track to accomplish—will enable these U.S. companies to vastly

currently growing. See also Third Way, *The Advanced Nuclear Industry: 2016 Update* (Dec.12, 2016), available at <https://www.thirdway.org/infographic/the-advanced-nuclear-industry-2016-update>.

³⁷ See, e.g., World Nuclear Association, *Nuclear Process Heat for Industry* (updated September 2020), available at <https://www.world-nuclear.org/information-library/non-power-nuclear-applications/industry/nuclear-process-heat-for-industry.aspx>; *Nuclear Reactors and Radioisotopes for Space* (updated February 2021), available at <https://www.world-nuclear.org/information-library/non-power-nuclear-applications/transport/nuclear-reactors-for-space.aspx>.

³⁸ See generally Department of Energy Office of Nuclear Energy, *4 Benefits of Advanced Small Modular Reactors* (May 28, 2020), available at <https://www.energy.gov/ne/articles/4-key-benefits-advanced-small-modular-reactors>.

³⁹ Clean Air Task Force, *Advanced Nuclear Energy: Need, Characteristics, Projected Costs, and Opportunities* (April 2018) available at https://www.catf.us/wp-content/uploads/2018/04/Advanced_Nuclear_Energy.pdf.

⁴⁰ Nuclear Energy Institute, *Micro-Reactors Could Power Remote Bases Within the Decade* (Oct. 4, 2018), available at <https://www.nei.org/news/2018/micro-reactors-power-remote-military-bases>; National Defense University Strategic Forum, *Small Nuclear Reactors for Military Installations: Capabilities, Costs, and Technological Implications* (Feb. 2011), available at <https://ndupress.ndu.edu/Portals/68/Documents/stratforum/SF-262.pdf>.

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de-risk their technology and enable them to finally be in a position to compete with Russia and China in the global nuclear market. Those nations likewise use their own nations as testbeds, with state support, for reactor designs they want to sell abroad—arguably without the same safeguards we apply here.

Please see the response to the question below for recommendations on what Congress can do to ensure that the U.S. can compete with Russia and China. Recommendations include streamlining the NRC process, ensuring financing is available for U.S. companies, which includes continuing to support the ARDP. I would also strongly suggest eliminating the Atomic Energy Acts foreign, ownership, control, or domination provision (FOCD), which only hinders cooperation with foreign companies and stifles U.S. advanced reactor development and deployment.⁴¹

Questions from Senator Steve Daines

Question 1: Ms. Roma, as a follow up to my question at the hearing, what specific federal regulations or federal laws should Congress and the administration reexamine to ensure a safe and quick deployment of new nuclear energy?

Congress should work to streamline the licensing process, which is often a roadblock in the development of nuclear technology. The current NRC licensing process is cumbersome and financially onerous. It is hard to point to an individual regulation that in itself creates a problem, but it is their implementation in the licensing process in which challenges occur. For example, it would not be unexpected for the NRC to take well over 6 years to license a new advanced reactor. This simply cannot work for the industry or the climate. We need a moonshot in this regard, with game-changing objectives that force new ways of thinking. For example, why can't the agency license a passively safe reactor in 2 or 3 years? And what would have to change to make that happen? When faced with an audacious goal that requires new and fresh thinking, like cutting licensing timelines by half, I believe the NRC staff will rise to the challenge.

Additionally, Congress can continue to finance advanced reactor development. The Advanced Reactor Demonstration Program (ARDP), a program DOE launched last year, provides cost-sharing incentives for companies developing advanced reactors. Initial recipients of the program—X-energy and TerraPower—received \$80 million each for their respective initiatives, which in return for being chosen, must demonstrate their projects by 2027, and there were a number of smaller ARDP awards to other companies with later deployment timeframes. Initiatives such as these, that rely on funding from Congress must be expanded. The Energy Act of 2020 authorized ARDP \$405 million for FY2021 and Congress must insure that funds continue to support this program.

As noted above, I would further recommend that Congress eliminate or significantly curtail the Energy Act's restriction on foreign, ownership, control, or domination (FOCD). The FOCD provision was established at the start of the Cold War when foreign involvement in nuclear power was seen as a threat.

⁴¹ See Nuclear Innovation Alliance, *Updating an Outdated National Security Framework* (Jul. 2018), by Amy Roma, Sachin Desai, and Alex Gilbert, available at <https://nuclearinnovationalliance.org/updates-outdated-national-security-framework>.

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This mindset is no longer in line with what is required today if the nuclear industry is expected to thrive. International partners play a key role in the U.S. nuclear industry and have large stakes in U.S.-based reactor designers and fuel cycle companies (such as uranium enrichment companies and fuel fabricators). Foreign investment from our allies, far from being viewed with skepticism, is instead critical for the U.S. civilian nuclear industry to succeed.⁴² U.S. allies are interested in supporting U.S. advanced reactor vendors, and often have higher tolerance for these investments than their U.S. counterparties.⁴³ However, instead of safeguarding American interests, the FOCD provision is more likely to push advanced reactor developers out of the country to demonstrate their technologies and will stifle investment in those that remain, harming U.S. nuclear technology leadership, U.S. nuclear export prospects (as there will be fewer U.S.-designed and built plants to thereafter export abroad), and overall nuclear security. And to be clear, elimination of the FOCD rule does not mean China can enter the US nuclear market. Among many other protections (such as the review by the Committee on Foreign Investment in the United States, or CFIUS), the NRC has the statutory obligation to deny any license that will be inimical to U.S. national security interests.

Question 2: Ms. Roma, like 21st century mining practices, 21st century nuclear energy is much different than it was in the past. What is industry doing to engage with the American people on the safety standards, high-paying jobs, and community benefits of modern nuclear energy?

There is a greater holistic appreciation today for public engagement and stakeholder input in developing and pursuing new nuclear reactor projects in the United States, and nuclear trade organizations, nuclear advocacy groups, and individual companies are more proactively explaining these benefits to people across the country.⁴⁴ Experience shows that unless the state and local community is in support of a project, it is difficult to successfully move forward the project through to successful completion. For example, communities are more likely to support an energy project if it promises to grow and sustain jobs. Nuclear has the highest paying jobs in the electric power generation sector—the average mid-wage worker is paid 22-25% more an hour when compared to other electric power sectors like coal and natural gas.⁴⁵ The average median hourly wage in the nuclear industry is \$39.19 compared to \$31.80 for the next highest in the energy industry.⁴⁶ Moreover, jobs in the nuclear industry pay 105% more than the national medium

⁴² *Id.*

⁴³ *Id.*

⁴⁴ See, e.g., Nuclear Energy Institute, *What is Nuclear Energy?*, available at [⁴⁵ See Energy Futures Initiative and the National Association of State Energy Officials, *U.S. Energy and Employment Report*, at 108, 113 and 119 \(2020\), available at <https://www.usenergyjobs.org/>; American Nuclear Society, *The U.S. Nuclear R&D Imperative: A Report of the American Nuclear Society Task Force on Public Investment in Nuclear Research and Development*, at 13 \(Feb. 2021\), available at <https://www.ans.org/file/3177/2/ANS%20RnD%20Task%20Force%20Report.pdf>; U.S. Department of Energy, Office of Nuclear Energy, *Advantages and Challenges of Nuclear Energy* \(Jan. 26, 2021\), available at <https://www.energy.gov/ne/articles/advantages-and-challenges-nuclear-energy#:~:text=Creates%20Jobs,higher%20than%20the%20local%20average>.](https://www.nei.org/fundamentals/what-is-nuclear-energy#:~:text=Nuclear%20energy%20provides%20more%20than,Nuclear%20protects%20our%20air.&text=Nuclear%20energy%20provides%20power%2024,Nuclear%20boosts%20international%20development; see infra notes 45-46.</p>
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⁴⁶ Energy Futures Initiative, *Wages, Benefits, and Change: A Supplemental Report to the Annual U.S. Energy and Employment Report* (2021) available at <https://energyfuturesinitiative.org/efi-reports>.

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(\$19.14).⁴⁷ Specialists in the field, like nuclear engineers and nuclear power operators, make more than double the national median wage.⁴⁸

Besides attractive and high paying job opportunities, nuclear also contributes affordable electricity rates for communities. A report analyzing the impacts of the retirement of nuclear power plants in Ohio and Pennsylvania estimated that retirement of these power plants would raise gross electricity costs for customers by about \$400 million and \$285 million, respectively.⁴⁹ Moreover, the four plants examined provide over 3,000 jobs, not including contractor positions, and also increases state GDP by hundreds of millions of dollars in addition to providing state and local tax revenues.⁵⁰

Safety standards in the nuclear industry are also being strictly observed and strengthened, giving communities assurances in support of facility siting and operation. The Nuclear Regulatory Commission's (NRC) regulatory requirements are considered the "gold standard" globally and has contributed to the increased safety standards in the nuclear industry over the past 25 years.⁵¹ The NRC's Reactor Oversight Process helps ensure safety and security of commercial nuclear power plants. Additionally, in over 60 years of nuclear power operation, there have only been two major accidents.⁵²

Question 3: Ms. Roma, the federal government and many states are not including nuclear energy in their carbon emission reduction plans.

I would like to preface my responses by clarifying that the federal government does support nuclear energy as an important element in its carbon emissions reduction plan and states are increasingly doing the same. Most recently, the President's \$2 trillion infrastructure plan—the American Jobs Plan—included multiple provisions on nuclear, including \$15 billion toward climate-related demonstration projects that included nuclear.⁵³ To add, federal agencies like the DOE and the Environmental Protection Agency are in favor of nuclear as part of the nation's climate plan. On top of that, twenty-seven states generated nuclear energy in April 2021.⁵⁴ With that said, continued, as well as increased and widespread recognition of the important tool that nuclear power offers the country is critical to ensuring that the U.S. government support translates into action.

⁴⁷ *Id.*

⁴⁸ *Id.*

⁴⁹ The Brattle Group, *Impacts of Announced Nuclear Retirements in Ohio and Pennsylvania* (April 2018), available at https://brattlefiles.blob.core.windows.net/files/13725_nuclear_closure_impacts_-_oh_pa_-_apr2018.pdf.

⁵⁰ *Id.*

⁵¹ Nuclear Energy Industry, *The Nexus Between Safety and Operational Performance in the U.S. Nuclear Industry* (Mar. 2020), available at <https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/NEI-20-04-The-Nexus-Between-Safety-and-Operational-Performance-in-the-US-Nuclear-Industry.pdf>.

⁵² World Nuclear Association, *Safety of Nuclear Power Reactors* (Mar. 2021), available at <https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/safety-of-nuclear-power-reactors.aspx>.

⁵³ The White House, *FACT SHEET: The American Jobs Plan* (Mar. 31, 2021), available at <https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/>.

⁵⁴ Choose Energy, *Nuclear energy generation by state*, available at <https://www.choosenergy.com/data-center/nuclear-generation-by-state/>.

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On the state front, twenty-seven states generated nuclear energy in April 2021, with Illinois, Pennsylvania, and South Carolina producing the most electricity from nuclear energy.⁵⁵ Currently, nine states include nuclear energy, in different generated electricity percentages, as part of their respective renewable portfolio standards (RPS) to incentivize zero-carbon emissions in the various clean energy plans.⁵⁶ Other, states like Illinois and New York have implemented zero emissions credits programs that place a value on a nuclear plant's emission reduction capabilities, which in turn helps support at-risk nuclear plants.⁵⁷ But more needs to be done to ensure the carbon-free nature of nuclear power is properly valued.

a) What countries have nuclear energy deployment as part of their carbon reduction plans?

Over fifty countries have nuclear in their energy portfolios and around 10% of the world's energy production is attributed to nuclear. Twelve countries receive at least 25% of their electricity from nuclear. Those countries include France, Belgium, Switzerland, and South Korea.⁵⁸ Additionally thirty countries are in the process of developing nuclear programs.⁵⁹ Most or all of these countries credit these nuclear power plants in one way or another towards their carbon reduction goals.

b) What should Congress and the administration do to include nuclear, hydropower, CCUS technology, and other baseload, carbon free generation in our energy goals?

Fighting climate change may appear daunting, but if the U.S. uses all available energy resources at our disposal a solution that meets the needs of our communities and businesses can be achieved. In essence, a diverse energy portfolio is needed to address diverse needs. Some clean energy technologies are better suited than others depending on the exact energy need. Effective and affordable energy solutions that also increase jobs and decrease reliance on foreign energy can only be accomplished if our energy portfolio is diversified. For instance, former Secretary of Energy Ernie Moniz's "Green Real Deal" approach looks to achieve an economy-wide decarbonization through a framework that provides all stakeholders a seat at the table and calls for a "comprehensive portfolio of energy technology." This includes what he refers to as technologies with breakthrough potential like advanced nuclear fission/fusion, hydrogen, and carbon capture.⁶⁰

⁵⁵ *Id.*

⁵⁶ See U.S. Energy Information Administration, *Summary of Legislation and Regulations Included in the Annual Energy Outlook 2021* at Table 1, available at <https://www.eia.gov/outlooks/aeo/assumptions/pdf/summary.pdf> (listing Connecticut, California, New Mexico, New York, Illinois, Nevada, New Jersey, Ohio, and Virginia as states with nuclear in their clean energy initiatives).

⁵⁷ National Conference of State Legislatures, *Status of U.S. Nuclear Reactors*, available at <https://www.ncsl.org/research/energy/state-action-in-support-of-nuclear-generation.aspx>.

⁵⁸ World Nuclear Association, *Nuclear Power in the World Today* (Mar. 2021), available at <https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx>.

⁵⁹ *Id.*

⁶⁰ Energy Futures Initiative, *What is the Green Real Deal?* available at <https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5d9217a7c9eeb9630c32d7ca/1569855403911/GRD+EFI+Part+2-2.pdf>.

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Questions from Senator Lisa Murkowski

Question 1: Can the Nuclear Regulatory Commission's current regulations regarding the transportation of licensed material be applied to the transport of microreactors?

Unlike conventional nuclear plants, where the components are built at a manufacturing facility, but are assembled at the plant site, nearly all a microreactor units may be built and assembled at the reactor manufacturing facility and then shipped to the desired site. This means that microreactor fuel must be shipped to the plant-manufacturing facility and loaded into the reactor at this facility.⁶¹ Shipping the completely assembled microreactor will require following Nuclear Regulatory Commission (NRC) and Department of Transportation (DOT) regulations for shipment of nuclear material.

DOT regulates shippers of hazardous materials, including radioactive material, and oversees vehicle safety, routing, shipping papers, emergency response, and shipper training. The NRC approves the design, fabrication, use, and maintenance of shipping containers for the most-hazardous radioactive materials, including spent nuclear fuel, and regulates the physical protection of commercial spent fuel in transit against hostile acts. In addition, the NRC in 10 CFR 71.5 requires materials shipments to comply with DOT's safety regulations for transporting hazardous materials.⁶² The type of packaging to be used during transport is determined by the activity, type, and form of the material to be shipped. Depending on these factors, radioactive material is currently shipped in one of three types of containers.

NRC is reviewing the existing Part 71 regulations to determine whether changes are required, or if new guidance must be developed to address transport of high-assay low enriched uranium (HALEU) fuel to a manufacturing facility and subsequent transport of a fully HALEU-fueled reactor to a site.⁶³ Industry and DOE, in cooperation with the NRC, should develop the necessary criticality benchmark data, to allow efficient and cost-effective licensing of a new generation of HALEU fuel facilities and transportation packages.

This is an important question considering that transportation of significant licensed material, like fuel, spent fuel, and enriched uranium are transported in licensed casks. The NRC has analyzed and confirmed best practices for this unique transport and it should undertake a similar approach in determining safe transport of microreactors. Considerations would include the quantity, level of fuel volume, and other associated risks.

To add, the NRC regulations do not currently contemplate that a reactor would be shipped fueled, as may be the case with a microreactor, and this is a matter the NRC would need to further evaluate if such a reactor were contemplated.

⁶¹ See Idaho National Laboratory in partnership with Department of Energy, *Key Regulatory Issues in Nuclear Microreactor Transport and Siting* INL/EXT-19-55257 at 6.1-6.3 (Sept. 2019) [hereinafter INL Report 2019].

⁶² Nuclear Energy Institute, *Addressing the Challenges with Establishing the Infrastructure for the front-end of the Fuel Cycle for Advanced Reactors* (Jan. 2018); Owusu, D., INL Summer 2018 Report, *Regulatory and Licensing Strategy for Microreactor Technology* (Aug. 2018).

⁶³ INL Report 2019 at 6.2.

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Question 2: Microreactors can recycle spent nuclear fuel, a current liability for the United States, by using High Assay Low Enriched Uranium (HALEU). What statutory or regulatory changes need to occur in order to have the Department of Energy provide the commercial nuclear industry with High Assay Low Enriched Uranium (HALEU) as fuel?

There are currently no HALEU enrichment services capabilities in the United States and most of the advanced reactor companies rely on HALEU.⁶⁴ The DOE supplies a small amount of HALEU for R&D purposes to advanced reactor developers from the existing U.S. stockpile, but the stockpile is expected to run out in the next decade or two. Importantly, the same stockpile is used for key U.S. defense needs, including providing fuel for the U.S. naval propulsion program.⁶⁵ To further the goal of standing up a domestic uranium enrichment facility for commercial HALEU, no statutory or regulatory change is needed other than directing DOE to do so through a competitive award process and funding the efforts. It would likely not make sense for DOE to stand up its own facility as its enrichment needs are fairly small and DOE is not permitted to compete with the private sector selling enrichment services.

Question 3: Another challenge is deploying these new nuclear technologies quickly and ensuring there are no unnecessary barriers to commercialization. While not directly in our Committee's jurisdiction, modernizing the Nuclear Regulatory Commission's review processes for these new designs is imperative to being able to deploy these designs and help us decarbonize quickly. With X-energy and TerraPower both submitting license applications to the NRC for the Advanced Reactor Demonstration Program, what will be the biggest challenge for your license application's review?

The biggest challenges will likely be keeping the NRC on time and on budget for its reviews and ensuring the NRC remains flexible to "right sizing" its review commensurate with the risks associated with the respective facilities. See my response to Question 1 from Senator Daines where I refer to a "moonshot" for reducing NRC licensing timelines to force new thinking within the agency.

Question 4: What actions can the Nuclear Regulatory Commission take to continue modernizing on a timeline that can help deploy new reactor designs?

The NRC should continue to explore ways to streamline the license review process for advanced reactor applications, including in the following area to name a few: shortening the length of the licensing review; more efficiently using staff resources; ensuring the focus of the NRC staff reviews aligns with licensing requirements; updating technical requirements for advanced reactors; right-sizing the regulations to align with risk; looking for regulations to eliminate due to inefficiency, redundancy, or non-applicability;

⁶⁴ See also Department of Energy's Office of Nuclear Energy, *What is High-Assay Low-Enriched Uranium* (Apr. 7, 2020) available at <https://www.energy.gov/ne/articles/what-high-assay-low-enriched-uranium-haleu>. Most of the advanced reactor companies rely on HALEU, which is not commercially made in the United States. The U.S. Navy has approximately 100 nuclear reactors in its submarines and surface ships.

⁶⁵ Center for Strategic & International Studies, *Back from the Brink: A Threatened Nuclear Energy Industry Compromises National Security* (July 2018), Michael Wallace, Amy Roma, and Sachin Desai, available at https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/180714_Wallace_BackFromtheBrink_Web.pdf.

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and looking for ways to further streamline the environmental review process to make it more efficient and more effective.

Question 5: There is a significant market for nuclear energy abroad, but if we lack a cost-competitive reactor design to sell, we will continue to cede our global leadership on nuclear energy to countries like China and Russia. To export these designs, we will also need better rules to streamline the export process and better financing opportunities through the Export-Import Bank and International Development Finance Corporation. Do you believe that the United States can use domestic sources of uranium as a strategic geopolitical tool?

Uranium comes with the restrictions associated with the country from which its mined. It attaches to the material for its lifetime. Domestic uranium does not have these restrictions, and therefore can be helpful for U.S. defense purposes. For this reason alone it is essential that the U.S. always maintain a domestic uranium industry. However, U.S. uranium is also critical as part of a larger nuclear export package to support the ongoing fueling of a facility overseas. After intense work to secure a contract and eventually build a new U.S. nuclear reactor overseas, we cannot have the customer turn around and have to buy its fuel from Russia or China.

Question 6: How can we better work with our allies to combat the financing China and Russia offer to developing countries that are allowing them to dominate the nuclear export market?

As previously noted, as a general matter, the U.S. needs to be more strategic, proactive, and coordinated in how it competes with Russia and China globally. To compete, the U.S. must establish a holistic approach with both energy and economics initiatives, and form better partnerships with the private sector. This would also enhance the U.S. ability to offer a coordinated, “one-stop” package worldwide, and could be done in coordination with our allies so that we are able to leverage strengths and capabilities of multiple commercial sector companies and government capabilities.

Question 7: If Congress was to direct the Nuclear Regulatory Commission in conjunction with their work with the Department of Defense on mobile reactors to conduct a study on the best practices or recommendations to streamline the regulatory process for advanced reactor designs, what criteria should be considered for the study?

One of the criteria in the Department of Defense (DoD) award for microreactors on forward operating bases was that the design could be licensed by the Nuclear Regulatory Commission (NRC).⁶⁶ Many of the additional criteria used by DoD that would make the microreactors beneficial for forward-operating bases make the technology attractive for commercial use: small, simple, factory-manufactured, air-transportable, able to be installed and operating within a matter of days, minimal operating needs, buried underground, and able to stay safe in hazardous conditions.

⁶⁶ U.S. Dept of Defense, *DoD Awards Contracts for Development of a Mobile Microreactor* (Mar. 9, 2020) available at <https://www.defense.gov/Newsroom/Releases/Release/Article/2105863/dod-awards-contracts-for-development-of-a-mobile-microreactor/>.

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If DoD were to work with the NRC on streamlining the licensing for micro-reactors or mobile reactors, the study should look at it from the same perspective: are there novel ways the NRC licensing process could be substantially reformed to meet military needs, that can then be applied to the commercial sector?

For example, right now every nuclear site needs its own license (each with an immense cost associated with obtaining and maintain the license, and taking many years to complete a licensing review). The military, which will likely want to use its reactor in a somewhat mobile fashion and deploy to new sites within days, cannot work with such an inflexible process. The NRC may have to embrace more flexible concepts as a result for licensing in order for the military to be able to effectively use a microreactor. Any study should evaluate these challenging licensing issues and how lessons learned in solving them could be turned around and applied for the benefit of the private sector. Applied to this example, can a mobile reactor concept piloted for the military then be applied to commercial reactors, enabling a mobile license framework that allows micro-reactors to deploy to a new site in days?

Other areas of review in the study can include the following: license review scope and requirements (including environmental reviews and the potential for a general or generic license), ongoing NRC oversight and licensing fees, siting, transportability, operator requirement/remote or automatic operations, physical security, emergency planning, fuel approval, and the need for an aircraft impact analysis.

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Questions from Ranking Member John Barrasso

Question 1: You mentioned that you will need high-assay, low-enriched uranium (HALEU) in 2024. The Energy Act of 2020 authorized the Department of Energy to carry out a program to support the availability of HALEU.

a) Is the Department taking the necessary steps to establish this program and make HALEU available? If not, why not?

HALEU is vital to most new advanced reactor designs, including many of the Advanced Reactor Development Program (ARDP) awardees. We believe that DOE understands the challenges relating to HALEU supply, and are confident that they are working to support the industry by ensuring that required HALEU supplies are available to the industry. However, as of today, there is not a publicly available strategy from the Department that describes how HALEU availability will be ensured. There are two key issues (1) timing of delivery and (2) available quantities.

Currently, DOE is conducting a cost-share program with Centrus Energy to demonstrate US centrifuge technology for HALEU production. This facility will provide a demonstration of a U.S.-origin enrichment technology, however, it is not a commercial plant and will have a very limited production capacity, commencing operations in 2022 with a predicted output of roughly 900 kilograms of uranium (KgU) of HALEU per year, which is well below our annual requirements.

We view the supply of HALEU as both a short-term issue and a long-term issue. The short-term challenge is to acquire enough supply for the ARDP program demonstration reactors, including the four-module Xe-100 plant and the TerraPower Natrium plant, which are scheduled to commence operations in 2027. To meet the aggressive, yet attainable time constraints of the ARDP, as authorized by Congress, X-energy must receive HALEU in sufficient quantities to begin fabricating the TRISO-X fuel for the first cores of our four modules by the fourth quarter of 2024. We have also been selected by Canada as one of three competitors for their small reactor program for deployment in 2028, only one year after ARDP deployment, and there are other domestic and international opportunities we are pursuing to immediately follow the 2028 Canadian deployment.

The long-term issue is to meet the escalating needs that we, and our competitors, will have after the initial demonstration of our reactors. There is a massive global opportunity to deploy advanced reactors in the 2030s and nearly all new-build projects are likely to require HALEU. In order to ensure a robust HALEU supply chain, there should be a competitive enrichment services supplier landscape with multiple commercially viable Western suppliers.

To meet this dual challenge, short- and long-term, we would like to see a two-fold strategy by the government. First, to address the short-term needs for the 2027/2028 timeframe, a strategy should be developed, promulgated, and supported by Congress that would be sufficient to meet the needs of X-energy, Terrapower, and other advanced reactors that need HALEU for the demonstration of their technologies in this timeframe.

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Such a plan could rely on a combination of mechanisms, including the purchase of material available in the commercial market, from domestic or foreign suppliers, and downblending of suitable material by the Department of Energy, to be replaced by the commercial market when it arrives. For imports, the Department could facilitate the acquisition of the required HALEU by acting as an intermediary and establishing a domestic HALEU bank. Such a bank could be established in partnership with a private sector consortium to ensure that it is sized appropriately for industry's short-term needs. Material that the Department currently owns that would be suitable for downblending is critical for our long-term national security requirements. There would also be associated costs for any such operations. A program that included downblending would need to take such important considerations into account to ensure that long-term national security needs are met in a timely fashion. If a DOE strategic HALEU plan is communicated clearly, with sufficient bipartisan support, and is funded at an appropriate level, without disrupting other critical-path priorities of the Office of Nuclear Energy, it will provide a strong signal to the domestic enrichment supply market that demand is, and will continue to be, sufficient to support investing significant capital to build and operate an enrichment capacity. As a private company, we will also continue to emphatically reiterate our growing long-term needs and seek opportunities with private sector suppliers to invest appropriate resources to stimulate a market response to our long-term needs, such that a Western supplier, preferably operating in the United States, is able to invest the resources to meet our needs.

b) Given sufficient resources, could the Department accelerate their efforts to meet your needs?

Yes. For the near-term to support the ARDP projects timeframe, the Department could meet the need by procuring HALEU fuel for a bank from today's existing foreign supplier. This should occur while the Department continues to support a long-term domestic capability as described in the previous response.

c) Beyond downblending stockpiles of material held by the Department, I understand that Russia is the only other current source of HALEU. Will you have to consider contracting with Russia if the Department is unable to fulfil its obligation under the Energy Act of 2020?

Yes. We are in the process of conducting proper due diligence into all potential near-term commercial suppliers of HALEU to determine all supplier possibilities.

d) Will you commit to acquiring HALEU from a supplier here in the United States, if such a supplier is available?

X-energy is committed to acquiring commercially supplied HALEU that is produced in the U.S., once such a market option is available at a fair price.

In fact, X-energy is committed to stimulating the U.S. nuclear fuel cycle industry and working with others in the U.S. industry to position the U.S. to regain its position as the global leader in the commercial nuclear industry. In this regard, X-energy is exploring options and partnerships for ways to accelerate the expansion of domestic HALEU production in the U.S.

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It is important to note that as part of ARDP, X-energy will construct a U.S.-based commercial TRISO fuel fabrication plant, which will require HALEU. This U.S. based fabrication plant will put the U.S. in a key position to be the world leader in providing particle coated fuel to many of the world's future advanced reactors.

X-energy wants to see the entire front-end of the nuclear fuel supply chain reestablished, and commercially competitive, in the U.S.

Question 2: Do you believe entities here in the United States can accelerate the development of enrichment capability to meet your HALEU needs?

Yes, we do believe that U.S. based production can be accelerated to meet future HALEU needs. There are a few commercial options available to achieve the goal of obtaining U.S. based enrichment capacity for the production of commercial production (e.g. in terms of production levels and competitive pricing). We are open to all creative solutions to enable such acceleration, including partnership with the Department of Energy.

Question 3: Advanced nuclear reactors can produce heat for industrial processes and other non-electric applications. What makes high-temperature gas-cooled reactors uniquely suitable for such applications?

HTGR reactors utilize helium as the coolant within the reactor core. The helium exits the core to the turbine at a very high temperature which generates high quality steam that can be used to generate electricity, generate process heat, or both. No changes need to be made to the reactor to produce process heat and generate electricity individually or together. This is one of the most attractive features of an HTGR. The temperature of the industrial process heat produced is high enough to meet the needs of many applications such as desalination, hydrogen production, or other industrial processes, as well as central heating, that currently use natural gas or coal. This is particularly important as we, as a nation, are trying to significantly reduce our dependence on fossil fuels, by addressing clean energy needs not only in the electricity sector, but the industrial sector as well.

Question 4: You mentioned that you are developing a mobile reactor to support defense applications. Will you please elaborate on this technology?

The Department of Defense interest in the potential benefits of a mobile nuclear reactor was driven primarily by two compelling issues: 1) the vulnerability of the existing fuel delivery supply chain, which has resulted in almost 50% of the casualties in Iraq and Afghanistan, and 2) the need for increased, reliable power for radars, weapon systems, and electrified vehicles.

The challenge to be addressed through the DOD's transportable reactor program is to reduce the warfighter's dependence on fuel supply while increasing mobility and lethality. The objectives are to develop and demonstrate a fission-based electricity delivery system that is small enough and light enough

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to be delivered to a site via C17 transport, that can be set up in 3 days, can be shut down and shipped within 7 days, and can deliver 1-3 MWe to the site for at least 3 years without fuel handling.

Additionally, in regard to safety of operators and military personnel, DOD is requiring the technology solution to utilize tri-structural isotropic (TRISO) ceramic-coated fuel, which has been developed with significant investment (approximately \$500 million) from the DOE over the past 10 years. This fuel was specifically selected due to its enhanced safety features and ability to withstand battle damage and high temperatures without breaking.

a) Would this technology be beneficial for disaster recovery and other applications?

Yes, it could be utilized in disaster recovery and other applications. There are obvious corollary applications for a power delivery system that can be flown in and operate autonomously for months at a time. Agencies focused on disaster relief, especially in support of island or remote communities, would benefit from this technology – allowing hospitals, communication systems, and water treatment facilities to get back up and running within a week. U.S. critical infrastructure, vulnerable to terrorist attack or long-term natural event damage to the grid, could be brought back on-line quickly if powered by this technology in an emergency scenario. Finally, northern remote communities that rely on oil or diesel could transition to this technology, improving air quality and mitigating weather-based interruptions to their electricity and heat supply. Many such communities are only able to receive diesel shipments twice per year, due to freeze-thaw cycles of navigable waterways (barged-in fuel), or require incredibly costly shipments by airplane in case of emergency.

Question 5: How can nuclear energy contribute to future National Aeronautics and Space Administration (NASA) missions, especially as it relates to the Moon and Mars?

As NASA lays out their human exploration and science missions, they recognize that traditional technologies will not be sufficient. Chemical propulsion systems are well-understood, but they cannot create the thrust needed to shorten the timelines of a human Mars mission – critical to astronaut health. Nuclear fission-based propulsion can reduce the travel time by 50%.

Permanent lunar habitats, or robotic assembly/mining capabilities on the lunar surface will require persistent, uninterrupted, reliable electrical power. The lunar night is long (14 Earth days) and cold (minus 200 degrees F). The size of solar arrays and batteries to survive these extreme conditions are significant. Only a nuclear power source can address these requirements.

Finally, deep space science missions are size/power limited if they use plutonium-based RTGs, and distance limited if they use solar arrays. Using compact fission-based nuclear to generate electricity to power the spacecraft and instruments, including powering an electric propulsion system to reach its destination, will enable a new generation of large, long-life, deep space missions to the outer planets and beyond.

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Question 6: What should the Department of Energy be doing to contribute to NASA's missions?

The Department is doing the right things to support NASA's long-term goals and missions. They are managing the development of nuclear thermal propulsion designs, through ground demonstration, to enable human Mars missions. They have developed, along with NASA Glenn Research Center, the requirements for a Lunar Fission Surface Power system, to demonstrate the delivery of 10 kW of power for over 10 years on the lunar surface – operated from a control center on Earth. Recently, the Los Alamos National Lab constructed and operated a small surface power prototype to show that the technology can be successfully scaled up. DOE/INL has also conducted extensive research on new fuel designs, in partnership with industry, using INL nuclear test facilities to characterize performance and ferret out infant mortality issues. Continued fuel activities should be continued on TRISO or other coated particle fuel at various regimes to meet a variety of potential missions.

In short, DOE's track-record of enabling NASA's mission needs has been exemplary. However, national space policy goals will require an expansion of this partnership and a redoubling of DOE's commitment to space activities with a proper long-horizon strategic view. Fortunately, DOE has recently increased its strategic commitment to NASA to enable its next-generation programs and is applying the right resources at this time. In particular, the Memorandum of Understanding between "NASA and DOE Regarding Energy-Related Civil Space Activities" executed in October of 2020 provides the strategic framework for long-term cooperation between the respective agencies and the continued execution of this MOU under the NASA-DOE joint executive committee should be encouraged. Finally, DOE's "Energy for Space: Strategy to Advance American Space Leadership," released in January of 2021 provides an excellent 10-year framework for DOE to be the "essential source of the science, technology, and engineering solutions needed for advancing U.S. leadership in the space domain."

Question 7: What do you consider the greatest risks to the success of the Advanced Reactor Demonstration Program?

The three biggest challenges that we face are (1) the availability of, and transportability of, HALEU to meet the timeframes needed to begin operations in 2027; (2) review times of our licensing applications by the regulator (NRC) for this new technology; and (3) consistent and reliable federal funding that optimally meets the development, licensing and construction schedule. For the X-energy ARDP proposal, the required funding curve for the years 2022 through 2027 is:

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\$M	85.2	122.6	216.2	272.9	324.3	165.6	44.8

To meet the schedule for deployment, X-energy's need for HALEU is the fourth quarter of 2024. This will enable fuel fabrication to occur in 2025 and 2026. X-energy will be fueling four modules, each with approximately 200,000 pebbles. Then the fuel will need to be transported and loaded into each of the modules in 2026 to enable start up in 2027.

On the licensing side, we assume that the NRC will meet their own guidelines for licensing, assuming they received adequate information from our ARDP team. However, any delay in their review process will impact our ability to meet our schedule.

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Question from Senator James E. Risch

Question: As the birthplace of nuclear energy, it is troubling that the United States has ceded much of its world leadership in nuclear to countries like Russia and China. If we are to reclaim this leadership, it is crucial that we act with urgency to demonstrate advanced reactors here in the U.S. Reactor development companies like TerraPower and X-Energy are leading the way to market. The Idaho National Lab is the nation's lead nuclear laboratory and home to the Nuclear Reactor Innovation Center (NRIC), which is helping to smooth the path for advanced reactor deployment. We've already demonstrated 52 reactors at INL, which is why there is no better place to demonstrate nuclear reactors than in Idaho.

It is my understanding that both of you engaged INL to support your technical scope of work. Can you share how the Idaho National Lab and the overall lab system has helped your companies prepare for the demonstration of your reactors?

The most significant contribution that INL has made to X-energy has been its critical work in support of the \$700M invested by the Department of Energy over the past 15 years in HTGR reactors, TRISO fuel, and licensing HTGR reactors. DOE's TRISO fuel and graphite irradiation program have developed fuel forms, irradiated them, and conducted post-irradiation analysis to a level that has allowed us to make this program the foundation for our fuel qualification program at the NRC for our commercial reactor. This foundation is invaluable to us as we license a new non-light water reactor, as expeditiously as possible.

In 2016, X-energy was awarded \$40M from the Department of Energy for the Advanced Reactor Concepts cooperative agreement to move forward on our reactor design, establish a pilot fuel facility, and engage with the NRC. As part of that cooperative agreement, 40% of the total funding supported work at DOE National Laboratories. In addition to the previous work on TRISO fuel characterization and analysis, we utilized INL for support of our Mechanistic Source Term analysis, which is critical in defining the emergency planning zone for advanced reactors. Additionally, INL's pioneering work with the NRC in identifying and addressing licensing issues for HTGRs and TRISO fuel, is the foundation for our licensing approach, which provides us with significant TRISO fuel testing analysis for fuel qualification. The investment that was made by the Department of Energy in HTGR reactors, fuel development, and licensing is an outstanding example of the critical role government programs can play. In particular, it exemplifies the important contribution of DOE National Laboratories in maturing technology sufficiently to enable a transition to industry, which is the bedrock of our first reactor commercial deployment under the ARDP program.

Questions from Senator Steve Daines

Question 1: Mr. Sell, the Montana State Legislature is working on legislation to study placing advanced nuclear reactors at closed coal powered units where the infrastructure for energy generation and distribution already exists. How can your technology help create jobs in rural communities and will you commit to working with Montana as they proceed with their study?

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Yes, I will commit to working with Montana to support the legislation and its objectives. Furthermore, X-energy will be glad to work with Montana on their study. In fact, our Xe-100 has been designed with retiring coal plants as a significant market opportunity due to their size, age of the fleet of plants and the trend to utilize more clean energy. Our standard four-pack Xe-100 plant produces 320 MWe, which was designed to meet the “sweet spot” of the replacement coal plant market. We believe advanced nuclear reactors like our Xe-100 provide the best carbon-free base load solution for this application.

Question 2: Mr. Sell, like 21st century mining practices, 21st century nuclear energy is much different than it was in the past. What is industry doing to engage with the American people on the safety standards, high-paying jobs, and community benefits of modern nuclear energy?

X-energy has a communications strategy that is focused on reaching out beyond the nuclear community to educate the public, other industries, the education community, and the media about the benefits of nuclear energy overall, and specifically the next generation of advanced reactors and their inherent increased safety, affordability, and production of valuable clean energy.

With our recent US DOE ARDP award to build the first Xe-100 plant in the USA in Richland, WA, not far from Columbia Nuclear Power Generating Station, X-energy, along with our partners, Energy Northwest and Grant County Public Utility District announced the TRi Energy Partnership as a joint effort to work with the communities and the state to educate and ensure support of this critical project. As part of our kick-off of this TRi energy Partnership we have spent time meeting with the local politicians, economic development groups, union leaders, and universities to talk about the project and educate them on the technology. This region has a long and proud nuclear legacy, but the impact of the facility will have larger a larger impact in the state as the first advanced reactor to be deployed. Washington’s Clean Energy Transformation Act enacted in 2019 is driving the state’s conversion to clean energy and a recognition that new nuclear must be a part of the solution. Communicating that value, and the advantageous features of a high temperature gas-cooled reactor, we view to be critical to the success of ARDP and our expansion into future markets. In fact, beyond creating 100s of new jobs in the area, successful deployment of our Xe-100 would leave a positive example of how the “modern nuclear energy” can contribute, in a most positive way, to our energy leadership both domestically and internationally.

Question 3: Mr. Sell, recycled or depleted uranium can now be used for the next generation of small nuclear reactors. What can we do to ensure access to recycled uranium?

X-energy’s reactor does not currently use recycled or depleted uranium. In my judgement, efforts to develop a program to recycle nuclear fuel should be a much lower priority. Today, we do not need to recycle nuclear fuel. The natural uranium market is still in a state of oversupply and U.S. mines have not returned to commercial production. The need to develop a capability to produce HALEU in the U.S. is a much higher and pressing priority.

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Questions from Senator Lisa Murkowski

Question 1: If Congress was to direct the Nuclear Regulatory Commission in conjunction with their work with the Department of Defense on mobile reactors to conduct a study on the best practices or recommendations to streamline the regulatory process for advanced reactor designs, what criteria should be considered for the study?

Broad deployment of microreactor technology in support of both fixed-site and emergent-need scenarios will be enabled by the same regulatory features that enable large commercial advanced reactors: a predictable, timely, and cost-efficient regulatory review process and on-going oversight commensurate with the safety-significance of such advanced reactor technologies. Criteria for evaluating best practices that streamline the regulatory review process should include considerations such as:

- Does a practice improve the efficiency of the review?
- Does a practice improve the timeliness of the review?
- Does a practice improve the predictability of the review? This includes being able to reliably estimate the costs, duration, and content (i.e., safety analysis reports, etc.) expectations.
- Does a practice improve stakeholder confidence in the outcome of the review? For instance, DoD's mobile reactor assessments follow a progressive approach that allows preliminary safety analyses to not only inform the next stage of design work, but also provide DoD/DOE/NRC technical data to evaluate the technology in a staged manner yet in a shorter overall period of time than currently employed in existing NRC practices.
- Does a practice focus on the most safety-significant review activities to ensure adequate protection? Risk-insights from existing technology, informed by design/site-specific information, and augmented with bounding deterministic analyses can allow for focused review activities that should be achievable in shorter periods of time.

Lastly, consider review metrics commensurate with the simplicity and lower risk of microreactor technology. For example, because micro-reactor power levels are orders of magnitude lower than commercial reactors, the source term, or threat to the public due to an anomaly, is commensurately orders of magnitude lower. That should be reflected in the cost to license the design and the time it takes to complete that license review.

Question 2: Congratulations on being selected by the DOE's Advanced Reactor Demonstration Program. The Energy Act of 2020 formally authorized the Program, which was part of the Nuclear Energy Leadership Act, and which has an ambitious timeline to demonstrate your designs. As you went through the ARDP process, what were some of the challenges and hurdles that you faced, or that you are aware other applicants faced, that you feel could be improved upon by DOE in order to better implement the future of the program and allow your companies to be successful?

The Energy Act of 2020 was truly transformative policymaking to achieve the ultimate goal of re-building our Nation's global nuclear energy leadership. Congressional recognition of both the need to establish such a program and the structure that was delineated to implement the program was crucial to enable the

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Department of Energy to act remarkably quickly to implement the program. The demonstration framework provided several key elements that are necessary to achieve the first step to achieve the ultimate objective. It provided an aggressive, but achievable timeframe, milestones to measure performance, and maybe most important, the requirement for a first customer. The 50-50% public-private partnership was a critical link to enable the first-of-a-kind plant to be economically attractive to an actual customer.

Finally, on the process side, we were extremely impressed with DOE's response to the Congress by releasing the Funding Opportunity Announcement five months after enactment of the law, and then were able to thoroughly conduct the evaluation of the proposals they received within four months. This was a complicated and game-changing opportunity in terms of technology leadership, economic viability, and the potentially significant contribution to global climate impacts and national security. The Congress and the Department of Energy fully recognized this imperative.

We do believe that it is critical for the Congress to focus on the three elements that must be addressed to enable success of not just these first two demonstration reactors, but for the advanced reactor community to flourish: 1. Providing HALEU when needed; 2. Assuring the regulator meets its required reforms and licensing timetables, and 3. Funding the program commensurate with the profile of a construction project.

Question 3: What do you see as the biggest challenges to meeting the congressionally directed goals, milestones, and timelines of the ARDP?

The three biggest challenges that we face are (1) the availability of, and transportability of, HALEU to meet the timeframes needed to begin operations in 2027; (2) review times of our licensing applications by the regulator (NRC) for this new technology; and (3) consistent and reliable federal funding that optimally meets the development, licensing and construction schedule. For the X-energy ARDP proposal, the required funding curve for the years 2022 through 2027 is:

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On the licensing side, we assume that the NRC will meet their own guidelines for licensing, assuming they received adequate information from our ARDP team. However, any delay in their review process will impact our ability to meet our schedule.

Question 4: What are some of the areas in advanced reactor technology in which we can better focus research and technology investments?

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Fuel design and performance is key to both safety and reactor performance (including economics). It is important to maintain strong research and irradiation programs of advanced reactor fuels.

Other important considerations could include test facilities that are applicable to the various types of reactor technologies. For example, in the case of X-energy we have the need for a Helium Test Facility. Consideration of what testing facilities might be needed early in the process could be helpful through the reactor design process.

Question 5: Another challenge is deploying these new nuclear technologies quickly and ensuring there are no unnecessary barriers to commercialization. While not directly in our Committee's jurisdiction, modernizing the Nuclear Regulatory Commission's review processes for these new designs is imperative to being able to deploy these designs and help us decarbonize quickly. With X-energy and TerraPower both submitting license applications to the NRC for the Advanced Reactor Demonstration Program, what will be the biggest challenge for your license application's review?

While many of the regulatory initiatives we intend to implement for ARDP are available today, some are only recently endorsed (i.e., NEI 18-04 from the Licensing Modernization Project), and some are in draft form or awaiting finalization through rulemaking or endorsed guidance, adding a measure of licensing uncertainty in both cost and schedule. We see ARDP as a means of demonstrating the resolutions to advanced reactor-related regulatory challenges in order to better inform the transformational regulatory framework being developed as required by NEIMA.

X-energy has been engaging with the NRC since 2015 and formally began our pre-application process for both our reactor and our fuel fabrication facility in 2018. We are anticipating that this engagement will lead to a more knowledgeable NRC staff, able to act expeditiously on our reactor and fuel facility applications, once submitted.

Question 6: What actions can the Nuclear Regulatory Commission take to continue modernizing on a timeline that can help deploy new reactor designs?

Changes to the regulatory framework for safety and environmental review activities that provide meaningful improvement to the predictability, efficiency, and timeliness of regulatory reviews are critical for deploying advanced reactor designs more broadly in the U.S. and internationally. In the near-term, developing a technology-inclusive advanced reactor regulatory framework in the proposed Part 53 that provides clear and understandable performance criteria, and, developing an efficient and predictable process that accelerates environmental reviews, such as through a simpler generic environmental impact statement, will allow advanced reactor technology to compete in the market and contribute as a meaningful climate change mitigation solution.

Question 7: I'm sure that your company would like to build many more reactors after your demonstrations through the Advanced Reactor Demonstration Program (ARDP). While the ARDP is extremely important for this effort, I want to look at what else can be done to help incentivize widespread deployment. One part of my Nuclear Energy Leadership Act that was not included in the Energy Act of 2020 was related to long-term power purchase agreements at Federal facilities.

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Would power purchase agreements at federal facilities be useful as you look to continue to deploy your advanced reactor designs?

Absolutely! The Federal Government being the largest employer in the country could be a shining example and role model to the country of how to truly achieve net-zero-emissions. PPAs would unlock not only advanced nuclear supply side activity but also further develop and mature the financial markets that support these companies. The American people will also benefit from this infrastructure improvement by economic stimulation that comes from increased high paying jobs, a cleaner environment, and reliable and resilient power production for key critical infrastructure.

**Grand Canyon Trust Briefing Regarding Senate Energy and Natural Resources
Committee Hearing on Nuclear Energy
March 25th, 2021**

We're submitting this briefing to provide perspective from the Grand Canyon Trust regarding tomorrow's SENR hearing on nuclear energy. The Grand Canyon Trust (the Trust) is a regional non-profit conservation organization whose mission is to safeguard the wonders of the Grand Canyon and the Colorado Plateau, while supporting the rights of its Native peoples. As the Southwest is our region of focus, we witness the devastating effects that uranium mining has historically had on our region and its people.

At the Trust, we work alongside diverse communities who are directly and adversely affected by ongoing uranium pollution in the Grand Canyon region, part of a vast and striking landscape with a complex history of exploitation, survival, and resilience. Communities throughout the Southwestern states of Arizona, Colorado, Utah, and New Mexico are on the frontlines of the climate crisis and the transition away from an extraction-dependent economy, including the lasting negative impacts from uranium contamination.

The history of exploitation – of lands and people - across the southwest is well-documented, and an all-of-government approach is needed to address uranium as part of the challenges regarding the future of the Colorado and the Southwest. This process should be innovative, equitable and comprehensive, and must protect our communities from duplicating the toxic legacy left by the last uranium boom. Thirty-one Native American Tribes occupy a quarter of the Colorado Plateau's land base, with a vast majority of the plateau considered ancestral lands, many of which have been disproportionately impacted by uranium and other extractive industries. Over 500 abandoned uranium mines are awaiting cleanup on the Navajo Nation alone, and many community members are facing the health effects from this toxic legacy even today. The Havasupai Tribe has for decades fought to protect their traditional homeland of Supai Village from the irreversible damage that would likely happen should their water become contaminated from uranium mining.

Rather than perpetuating this inequitable legacy, Congress should set forth a vision of innovation and preservation while providing tribal and local economic opportunities that do not build upon the tragic legacy of uranium pollution and disrespect of tribal rights.

Leaders in Congress working with communities can elevate the Southwest as a model for a sustainable, equitable, and tribally-driven future, inclusive of all communities and protective of the lands, waters, and resources on which we all depend. Additionally, Congress should look forward toward economic resilience – including by building critical infrastructure for the region's Tribes that should have been done decades ago, and whose absence has been laid bare by the COVID-19 pandemic. Below, you will find selected items for your consideration regarding uranium in the Southwest in tomorrow's hearing.

Legacy of uranium contamination

- There is an unfortunate and tragic history of uranium contamination in the Southwest, which has disproportionately impacted Tribes and communities of color.
- Uranium companies often claim that they can clean groundwater and return it to pre-mining conditions, but we have seen no evidence this has ever been done, or is possible.

- Tuba City Disposal Site, an abandoned uranium mill on the Navajo Nation, sat unfenced, and with no warning signage, while continually emitting radioactive pollution.
- Churchrock, New Mexico is home of the [largest radioactive spill in U.S. history to date](#), also on the Navajo Nation.
 - Communities near this disaster site were never informed of the dangers or level of radioactive exposure and as a result there has been an increase in various cancers and other health disparities.
- Tribal communities have suffered the majority of the permanent damage from radioactive contaminants and the nuclear fuel chain including impacts to land, air, water, and human health.
- New plans to send radioactive tailings from abandoned mines on the Navajo Nation to the White Mesa uranium mill near the Ute Mountain Ute community merely transfers the burden from one tribal community to another.

Newer does not equal safer

- The United States' last conventional uranium mill still poses risks and is not exempt from accidents and contamination of air, land, and water.
 - Opened in 1980, the White Mesa Mill, adjacent to the Ute Mountain Ute Tribe's White Mesa community, processes not only uranium ore, but also [imports low-level radioactive waste](#). After uranium is extracted from the waste, the toxic and radioactive leftovers are dumped on site forever. Though the mill was not envisioned as such, it now effectively functions as a low-cost radioactive waste dump.

Taxpayers continue to shoulder the burden of uranium extraction

- From the 1950s to current day, the government-funded uranium industry in the United States has always stood on the shoulders of the taxpayer.
- Indigenous communities have been disproportionately impacted by pollution associated with uranium mining and milling, and as companies declare bankruptcy and walk away, taxpayers are left to cover the cleanup costs.
- In 2020, congress appropriated \$75 million to create a "strategic uranium reserve." This means using taxpayer dollars to pay uranium companies above-market price for their product despite a flooded global uranium market that, since the 1980s, has seen little demand for additional lower-quality, and therefore higher-cost, U.S. uranium.
 - The original \$150 million dollar proposal was reduced after a [Government Accountability Office report](#) found that "DOE officials could not provide supporting data" to explain how the original \$150 million budget proposal had been calculated.

Biden Administration has prioritized Environmental Justice

- Executive orders under the Biden administration prioritize environmental justice.
- Congress must recognize that uranium is an environmental-justice issue — one that cuts deeper for rural and Indigenous communities across the United States, many whose

lands have been contaminated by uranium mining, and whose public health has been adversely affected.

Uranium as a critical mineral

- The Trump Administration's inclusion of uranium as a critical mineral by executive order in 2018 should be rescinded.
- Its inclusion as a critical mineral serves as a significant barrier to strategic planning with local, state and federal interests regarding extraction, reclamation and economic development in the southwest.
- The Trump Administration departed from scientific expertise to classify uranium as a critical mineral, as uranium is a fuel source and not a critical mineral by definition.
- The Navajo Nation opposed uranium critical minerals designation. Resolution found [here](#).
- Continuation of this designation could further inequity and could inhibit economic advancement in the southwest.
- Detailed testimony from 2019 opposing the designation of uranium as a critical mineral from Sharon Skaussoni, Research Professor of the Practice of International Affairs George Washington University, can be found [here](#).

HEARING ON NUCLEAR ENERGY
SENATE COMMITTEE ON ENERGY AND NATURAL
RESOURCES

MARCH 25, 2021

COMMENTS FOR THE RECORD
OF

PAUL N. CICIO
PRESIDENT & CEO
INDUSTRIAL ENERGY CONSUMERS OF AMERICA
1776 K STREET, NW, SUITE 720
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EXECUTIVE SUMMARY

Chairman Manchin, Ranking Member Barrasso, thank you for holding this important hearing on nuclear energy.

As some of the largest manufacturing electricity consumers in the U.S., we support efforts to develop and deploy cost-competitive nuclear energy units, including smaller modular units potentially for our use. We also support relicensing of existing nuclear units. Due to its reliability attributes, nuclear energy is essential to addressing climate change.

IECA is a nonpartisan association of leading manufacturing companies with excess of \$1.0 trillion in annual sales, over 3,700 facilities nationwide, and with more than 1.7 million employees. IECA membership represents a diverse set of industries including: chemicals, plastics, steel, iron ore, aluminum, paper, food processing, fertilizer, insulation, glass, industrial gases, pharmaceutical, building products, automotive, independent oil refining, and cement.

COMMENTS FOR THE RECORD

Importance of cost-competitive nuclear power: Technology and permitting solutions are needed which will result in cost-competitive nuclear power. Most IECA companies are energy-intensive trade-exposed (EITE) industries, which means that the price of electricity can determine competitiveness relative to foreign competitors. For manufacturing, cost-competitive power is needed to enable U.S. investments and job creation. EITE industries consume about 80 percent of the energy consumed by the total U.S. manufacturing sector.

Importance of reliable power: The manufacturing sector operates 24/7, which means we need reliable power. The intermittency of renewable energy is already negatively impacting power quality. Poor power quality can negatively impact production of products, and damage products and equipment. With increased renewable power generation, maintaining a minimum of reliable baseload power generation is essential. With the reduction of coal generation, increased baseload nuclear power generation is of increasing importance.

Importance of electric generation that produces steam for the EITE industries: Modular nuclear energy generators are of interest because it generates steam energy. A significant portion of EITE industries use steam energy to operate facilities. EITE industries are often co-located near one another, which makes it easy for one nuclear unit to generate steam for multiple manufacturing sites, therefore avoiding use of fossil energy and GHG emissions. We urge the Senate to make industrial size nuclear generators an integral part of the strategy to rejuvenate U.S. nuclear power generation.

Importance of non-emission power generation: Nuclear power generation is the only baseload power source that does not have emissions and is essential to meeting climate change challenges.

Page 3
Industrial Energy Consumers of America

Importance of diversity of generation sources: Consumers benefit when there is diversity of generation sources that compete with one another. Competition between and among generation sources yields lower prices and better service. With the reduction in coal use, cost-competitive nuclear energy is needed to fill the void.

We look forward to working with you to advance cost-competitive nuclear energy.

Sincerely,

Paul N. Cicio
President & CEO
Industrial Energy Consumers of America
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(202) 223-1661

**Testimony of NuScale Power
before the
Senate Energy and Natural Resources Committee**

“The Latest Developments in the Nuclear Energy Sector with a Focus on Ways to Maintain and Expand
the Use of Nuclear Energy in the United States and Abroad”

**John L. Hopkins
Chairman and Chief Executive Officer**

NuScale Power
6650 SW Redwood Lane
Suite 210
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March 25, 2021
Submitted for the Record on April 8, 2021

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**John L. Hopkins
Chairman and Chief Executive Officer
NuScale Power**

March 25, 2021

Submitted for the Record on April 8, 2021

Thank you for the opportunity to testify before the Committee today.

The United States is on the cusp of an accelerated transition to a clean energy economy as the urgency to address climate change grows. Today, the potential for a truly carbon-free power sector is moving closer to reality, in part due to the evolution of advanced nuclear technologies. Advanced Small Modular Reactors (SMRs) offer a near-term opportunity for true decarbonization with safe, flexible, efficient and affordable zero-carbon baseload technology that will help drive growth in the clean energy economy.

The development of this advanced nuclear technology was made possible by the cost-shared, public-private partnership model employed by the Department of Energy and Congress over the last decade to demonstrate commercial-scale, first-of-a-kind advanced nuclear technology to reduce deployment risk and to re-establish the United States as the global leader in nuclear power. The model is working.

2020 was a very big year for advanced nuclear:

- In August 2020, NuScale Power’s SMR made history as the first and only SMR to receive approval of its design by the Nuclear Regulatory Commission (NRC). NuScale’s 12,000-page design certification application (DCA) took more than 2 million engineering hours, involved more than 800 people, and cost \$500 million to prepare.
- The NRC concluded that NuScale Power Modules can shut-down and self-cool for an unlimited period of time with no operator action, no need for additional water, and no electricity. By comparison, existing nuclear facilities and other advanced technologies have coping periods that range from minutes to days. Due to these safety features, in the U.S., the emergency planning zone for a NuScale plant can justifiably end at the site boundary rather than default to the 10 mile emergency planning zone that exists today for traditional nuclear facilities.
- NuScale’s SMR is the first advanced nuclear technology to go through the NRC process, taking just 42 months and finishing on-time. This success came after years of collaboration between NuScale and the NRC.

NuScale secured and signed an agreement with its first customer, the Utah Associated Municipal Power Systems (UAMPS), that will start commercial operation of its first NuScale SMR by 2029 to supply power currently provided by coal plants that will retire this decade. UAMPS is pursuing “all of the above” in replacing this generation – wind, solar, storage and energy efficiency – but still needs a reliable, flexible source like a NuScale power plant to keep the lights on. UAMPS is a political subdivision of the

State of Utah that provides comprehensive wholesale electric-energy, transmission, and other energy services, on a nonprofit basis, to community-owned power systems throughout the Intermountain West. UAMPS members are located in Utah, California, Idaho, Nevada, New Mexico and Wyoming.

Together, these facts make the NuScale Power SMR the only near-term deployable and commercially viable advanced nuclear generation solution that is poised to deliver transformational clean energy change in the power sector, both domestically and internationally.

Today I will provide an update on the state of advanced SMR technology and NuScale Power's progress, describe the opportunity to maintain and expand the use of nuclear energy to address climate change in the United States and abroad, and articulate policy actions that can help speed this transition.

Advanced Nuclear Technology: Small Modular Reactors

SMRs are a new type of smaller, safer nuclear reactors designed to provide flexible and cost-effective nuclear power solutions. NuScale Power is the leading developer of American SMR technology. The genesis of our 77 MWe light water reactor began twenty years ago with a U.S. Department of Energy (DOE) grant and the construction of a one-third scale electrically-heated prototype test facility to validate the safety features of the plant. This prototype has been in operation since 2003 and led to our founding in 2007 with a handful of employees and three patents.

NuScale is based in Corvallis, Oregon and majority-owned by the Fluor Corporation, headquartered in Irving, Texas. Our corporate offices are in Portland, and we now have more than 400 employees in five offices in the U.S. and one office in the UK. We are frequently called upon by the International Atomic Energy Agency and others to present on our technology and achievements. We have memorandums of understanding for the deployment of NuScale SMRs in 11 countries, two of which are supported by letters of intent from U.S. EXIM and the U.S. Development Finance Corporation.

NuScale SMRs have revolutionized nuclear safety with a simplified design and walk-away safe technology. NuScale Power Modules can shut-down and self-cool for an unlimited period of time, with no operator action, no need for additional water, and no electricity. This unlimited coping period is a first of its kind innovation – existing nuclear facilities and other advanced nuclear technologies have coping periods that range from minutes to days. We accomplished this by the use of natural forces of physics (convection, conduction and gravity) rather than outside power sources, to drive the flow of coolant in the reactor thereby enabling the elimination of over two-thirds of the safety-related systems and components found in existing operating nuclear power plants. Protected by more than 560 patents granted or pending in nearly 20 countries, this technology has been demonstrated through an extensive test program inspected by the U.S. Nuclear Regulatory Commission (NRC). Due to these safety features, in the U.S., the emergency planning zone for a NuScale plant can justifiably end at the site boundary rather than default to the 10 mile emergency planning zone that exists today for traditional nuclear facilities.

NuScale's SMR is powered using the same fuel that is used today in our existing reactor fleet. This helped speed the NRC licensing process and leverages the extensive supply chain and solutions for the provision of the fuel and the disposition of the used fuel.

Each NuScale power module can generate up to 77 MWe of electrical power and up to 12 modules are housed at each site, providing up to 924 MWe. The modular design allows investments in generating capacity to be right-sized for the application at hand and provides the flexibility to grow over time. SMRs are factory built and can be delivered by truck, rail, or barge to the site. Completing the construction

design before construction begins in the field will reduce the risk of cost overruns and schedule delays that have plagued large-scale nuclear construction.

SMRs can provide zero carbon, load-following, baseload power integrated with intermittent renewable energy sources like wind and solar, reducing the need for fossil-based backup. NuScale plants can change power generation with the use of the highly maneuverable core design or, for rapid changes in power output, a “turbine bypass” feature can direct steam away from the steam turbine generator. With this technology, zero-carbon options like wind and solar can thrive without relying on fossil-based generation or expensive battery storage - while maintaining grid stability.

The NuScale SMR was designed deliberately for operational flexibility to facilitate decarbonization of a diverse range of nonelectrical applications, including water desalination, district heating and hydrogen production. These applications are traditionally powered by fossil fuels; the NuScale plant provides a reliable, zero carbon power alternative.

NuScale Power: Leading the Transition

The regulatory and capital investment risks associated with development and deployment of first-of-a-kind nuclear technology can often prove to be insurmountable. As with many new clean energy technologies, the type of Federal cost-share support provided by the Department of Energy’s Advanced Small Modular Reactor R&D program is a key factor in derisking these investments.

Before a commercial nuclear technology can be deployed in the United States, it must be approved by the NRC. Customers who will purchase and operate an NRC-approved design can also receive their own Combined License (COL). The process to achieve NRC approval for the technology and customers’ receiving a COL can present significant risks as they require large up front investments without any certainty as to the final outcome. To help overcome these risks, DOE has been supporting programmatic, cost-shared public-private partnerships to advance the development of these technologies through licensing and demonstration with the Department of Energy’s Advanced Small Modular Reactor R&D program, and it is working. NuScale received its NRC approval in 2020 and its first customer, UAMPS, has begun its application process.

In 2013, NuScale won a competitive DOE 50-50 cost-shared funding opportunity from the DOE to develop a DCA and demonstrate a commercial scale SMR. Fluor and NuScale’s investors contributed \$675 million, or 61% of expenditures to date, and the Federal government has contributed \$425 million, or 39%. As we continue to advance our technology, we are continuing to seek investors and partners consistent with the terms of our public-private partnership. In fact, on April 5, NuScale announced a \$40 million investment and strategic partnership agreement with JGC Holdings Corporation (JGC HD), a holding company of one of the world's leading EPC contractor group companies headquartered in Japan.

As I mentioned previously, NuScale crossed a major milestone in 2020 when the NRC approved its design. NuScale is the only SMR design to receive NRC approval. The 12,000 page design certification application (DCA) took more than 2 million engineering hours, involved more than 800 people and cost \$500 million to prepare. It was submitted in January 2017. The NRC accepted it for review in March 2017 and completed ahead of the established 42-month schedule. As a follow on, in 2020, DOE awarded a new cost-share award that is currently planned to provide \$263 million in federal funding to complete the NuScale design and ensure the ready availability of the equipment and materials that go into a NuScale plant.

With continued appropriations for the Department of Energy's Advanced Small Modular Reactor R&D program, Congress and the Administration can ensure that NuScale's zero carbon advanced nuclear technology will complete the design process and enable delivery of their first module by 2027.

Today, NuScale is the only near-term, commercially deployable advanced nuclear technology. In addition to being the only SMR design to receive NRC approval, it is the first technology to sign an agreement with a utility partner, the Utah Associated Municipal Power Systems (UAMPS). We are preparing for our first deployment project known as the Utah Associated Municipal Power Systems (UAMPS) Carbon Free Power Project, which will be sited at the DOE's Idaho National Laboratory (INL) site. The NuScale power plant will generate electricity for UAMPS' customers in Utah, Nevada, New Mexico, and Idaho. In 2020, UAMPS received a 25% DOE cost-share grant to support licensing and demonstration of this first-of-a-kind commercial scale plant.

Let me be clear: the cost-shared funding provided by Congress has accelerated NuScale's advancement through a complex NRC Design Certification process. This is what Department of Energy's Advanced Small Modular Reactor R&D program was created to do, and our success is credited to your strong bipartisan support. This work has paved the way for future advanced reactor technologies, and we are proud to have led the innovation pipeline in the United States.

But, the work is not yet complete. Until a commercial scale advanced SMR is fully operational, the U.S. will be unable to fully capitalize on the potential to deploy advanced nuclear technologies domestically and abroad. At this point in our development process, we are turning to proof of concept testing, manufacturing trials, detailed design, and development of procurement specifications for the unique safety-significant components of the NuScale Power module, such as the control rod drive mechanisms, reactor pressure valves, containment isolation valves, reactor building cranes, underwater bolting equipment and other long lead items. With continued appropriations for the Department of Energy's Advanced Small Modular Reactor R&D program, Congress and the Administration can ensure that NuScale's zero carbon advanced nuclear technology will complete the design process and enable delivery of their first module by 2027.

Delivering Emissions Reductions and Growing the Clean Energy Economy

Advanced SMRs offer a near-term opportunity for true decarbonization with safe, flexible, efficient and affordable zero-carbon baseload technology that will help drive growth in the clean energy economy.

A 924 MWe NuScale plant would eliminate over 8 million tons of CO₂ emissions per year (as compared to coal)—the equivalent of taking 1.7 million cars off the road for a year. Building a 924-MWe NuScale plant instead of a natural gas plant would eliminate nearly 4 million tons of CO₂ emissions per year—the equivalent of taking over 800,000 cars off the road for a year.

Studies by MIT, the International Energy Agency and E3 demonstrate that moving to a low carbon economy with nuclear is far more affordable. MIT reported that without nuclear energy, the cost of deep decarbonization of the electricity sector would be two to three times higher. E3 reported that without nuclear energy, achieving Washington state's 100% clean electricity standard by 2045 would cost \$8 billion more per year. Energy Northwest has sponsored studies that forecast a need of up to 5GW of "NuScale-like" dispatchable nuclear power for Washington state electricity suppliers to affordably supply 100% clean energy to their customers by 2045.

A NuScale plant is similar in power output to an existing coal plant and can comfortably fit on the same site, re-use the existing transmission infrastructure and most importantly, retrain and retain the coal plant workers to build and operate the NuScale plant.

A NuScale plant represents a century-long investment in a community, including 1,200 construction jobs over three years with significant needs for heavy equipment operators, welders, electricians, pipefitters and plumbers, and others. Fluor has executed a Memorandum of Understanding with the North American Building Trades Union for the construction of NuScale plants in the United States.

A 12-module NuScale plant is expected to support 270 operation jobs for sixty years and 677 induced/indirect jobs for sixty years. This is about twice the workforce of a similarly-sized coal plant and six times that of combined cycle natural gas plant. Jobs at a nuclear plant pay 20% more on average, and three-quarters of the workforce will require skills obtained through completion of an associate's degree, vocational training, or military training. Additionally, a 12-module NuScale plant is expected to generate approximately \$16 million per year in local taxes and \$470 million per year in local goods and services.

By re-using the coal plant site and retaining the coal plant workforce, there is minimal impact to workers and families while the community that grew-up with the coal plant retains the local tax contributions and symbiotic economic ties for another 40 years or more.

Writ large, there are currently 220 coal plants operating in the U.S. that will be over 60 years old by 2040. That represents 145 gigawatts of electricity capacity that could be replaced by 150 NuScale plants. Transitioning those coal plants to advanced SMRs would generate 1.7 billion hours of construction employment, preserve or create 40,000 power plant jobs, preserve or create 40,000 manufacturing jobs and eliminate 1 billion tons of carbon dioxide per year.

Once deployment begins, NuScale's innovative manufacturing process along with investments in SMR technology will help grow the clean energy economy and build a significant supply chain. Since NuScale SMRs are smaller, as production grows, they will be built in a factory and transported to each project site rather than being built on site.

Our supply chain is already extensive, with 52 supplier partners located in 23 states. For example, Sargent & Lundy is an engineering firm headquartered in Chicago. The company currently has 70 engineers dedicated to completing the NuScale Standard Plant Design. Framatome, formerly called Areva, which is headquartered in Lynchburg, Virginia, will manufacture fuel assemblies at their facility in Washington state. Our progress through NRC licensing is already stimulating investment in the U.S. manufacturing sector. The domestic supply chain for manufacturing three NuScale plants per year could generate about 13,500 direct jobs and \$2 billion in direct and indirect benefits from manufacturing and construction activities over 4-year construction period.

The nuclear workforce in the United States is growing as a result of innovation in advanced SMR technology. NuScale and Fluor have collaborated with U.S.-based universities on over 20 research projects to support the reactor design. DOE has also announced grant funding to support deployment of a simulator of the NuScale small modular reactor power plant control room at Oregon State University, Texas A&M at College Station and the University of Idaho. The simulators will be used for research and education.

Policies to Accelerate Deployment of Advanced Small Modular Reactors

Given these advantages, advanced SMRs can offer a transformative solution on our path to decarbonization. However, the risks involved in development of first-of-a-kind technology and the extended and costly uncertain regulatory approval process, can create hurdles. DOE's ongoing public-private partnership for SMRs has been and remains the most critical factor in the successful advancement of this technology to date as we move toward commercial deployment. Successfully moving the first advanced nuclear technology through the NRC licensing process to demonstrate a commercial scale reactor is the key to unlocking investment and the domestic and international markets for U.S. advanced nuclear technologies.

Continued resources for DOE's public-private partnerships must be a priority for Congress. Cost-shared grant funds will be used by NuScale and its utility partner, UAMPS, for acceleration of design finalization activities, development of the manufacturing supply chain, and site licensing and deployment activities. Further, NRC should have sufficient resources assigned to process advanced nuclear applications in a timely manner.

Recent proposals for a clean energy investment tax credit would go a long way to mobilizing the trillions of dollars invested in clean energy investment funds that could be used to fund this six trillion dollar investment in clean energy infrastructure.

The American Jobs Plan proposed by President Biden calls for reliance in part on the carbon-free energy provided by nuclear power while working toward the goal of 100% clean power by 2035. Additional investment in the advanced nuclear sector as part of an infrastructure package will speed progress, create jobs, attract investment and grow the supply chain more quickly. As the U.S. Congress and this Committee considers policies to accelerate the transition to a clean energy economy, I want to note the potential contribution advanced SMRs such as NuScale could make towards a clean energy transition that brings coal plant communities and workers along with jobs and economic activity. Policies that provide financial support to coal plant communities should consider the transition to advanced SMR clean energy as part of those programs.

Conclusion

The NuScale SMR is a disruptive technology that will change the way the world views nuclear energy and will play an important role in the next generation deployment of zero-carbon baseload sources of electricity.

NuScale is proud to be developing a new innovative advanced SMR technology that sets a new safety standard for nuclear energy facilities, is carbon-free, factory-built, incrementally deployable, capable of load-following, and affordable. Replacement of coal-fired generating assets with SMRs can spur growth in the clean energy economy and create workforce opportunities.

We are grateful for the support of the DOE and the Congress. We take the responsibilities associated with the use of taxpayer dollars very seriously and are singularly-focused on our role in the re-establishment of U.S. leadership in nuclear technology. We are proud to be paving the way for future advanced reactor technologies.

I want to thank the Committee for the opportunity to testify before you today, and I look forward to your questions.



7130 W. Grandridge Blvd., Ste. A | (509) 735-1000
 Kennewick, WA 99336-7725 | TryTri-Cities.org

March 24, 2021

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

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

Dear Chairman Manchin and Ranking Member Barrasso,

On behalf of the Tri-City community in Washington state, we write to express our sincere appreciation for your leadership and support of nuclear energy, and to thank you for holding a hearing to discuss how to maintain and expand its use. In particular, we are encouraged by the opportunities associated with the Department of Energy's Advanced Reactor Demonstration Program (ARDP).

As background, the Tri-City Development Council (TRIDEC) is the lead economic development organization for the Tri-Cities, WA, with a Board of Directors that includes elected officials from all nine of the local governments in our community. We are proud of the Tri-Cities' legacy of achievement in nuclear technology development, beginning during the Manhattan Project and continuing to this day.

The ARDP is an extraordinarily important program, in part because it will re-establish the United States' position as a global leader in nuclear technology development and deployment. This will in turn create tremendous opportunities for U.S. job creation in the manufacturing and export of these new advanced reactors. Additionally, advanced reactors and small modular reactors (SMRs) will play a critical role as one of the few new sources of clean, safe, and affordable baseload power that is adaptable to market needs.

The ARDP is also a very ambitious program, aiming to achieve deployment of these reactors by 2027. In recognition of this, we hope that Congress will provide the funding necessary to successfully achieve the program's goals.



The Tri-Cities is currently home to Energy Northwest's Columbia Generating Station, the Pacific Northwest's only commercial nuclear reactor. Energy Northwest has partnered with X-energy and TerraPower on their ARDP projects, which could lead to our community hosting one or both of these advanced reactors in the future. We are extremely excited about this opportunity and believe it will open the door to a whole new chapter of nuclear leadership for our community.

In closing, we would like to again thank you for your efforts to support nuclear energy and the ARDP. The Tri-City community looks forward to doing all that we can to contribute to their success in the future.

Sincerely,



Karl Dye
President & CEO



David Reeploeg
Vice President, Federal Programs

cc: The Honorable Maria Cantwell, United States Senate
The Honorable Patty Murray, United States Senate
The Honorable Dan Newhouse, United States House of Representatives



**Canada Embraces Nuclear Energy Expansion to Lower Carbon Emissions:
Government is encouraging the deployment of small modular reactors, making the country
an exception in the developed world**

March 3, 2021

**Paul Vieira and Peter Landers
The Wall Street Journal**

OTTAWA—In most developed nations, enthusiasm for expanding nuclear power is limited or nonexistent. One exception: Canada.

It is counting on nuclear power to be part of its clean-energy mix, which will play a prominent role in sharply reducing carbon emissions. On a per-capita basis, Canada's carbon emissions are in line with the U.S. and greater than in Russia, China and India.

"We don't see a path where we reach net-zero carbon emissions by 2050 without nuclear," said Seamus O'Regan, Canada's natural-resources minister. "It is proven, it is tested and it is safe. We are good at it."

Canada ranks sixth among countries in terms of nuclear-power generation, according to the Washington, D.C.-based Nuclear Energy Institute. Electricity produced from 19 nuclear reactors accounts for 15% of the country's energy supply. In Ontario, an economic engine that is bigger in area than the state of Texas, nuclear power is the top source of electricity, at 60%.

Late last year Canada's federal government set out a policy road map to encourage the deployment of what are known as small modular reactors, or SMRs. They are a new class of reactors that are built in factories and come in a range of sizes. They can produce enough energy for a town as small as 5,000 in population or a city as big as 300,000.

Unlike legacy reactors, which are built on site and big enough to power a city of a million or more, these smaller versions can be transported and dropped into locales where they are either hooked up to the electricity grid to serve a large region, or meet the needs of industrial areas or small towns. Proponents add that SMRs are more efficient in producing electricity compared with legacy reactors, and that their costs make them competitive with fossil fuels such as natural gas and coal.

Canadian officials regard small modular reactors as a way to provide electricity to remote, northern indigenous communities, some of which are fueled by diesel. Two western oil-rich provinces, Alberta and Saskatchewan, count on fossil fuels to generate the bulk of their electricity, and neither has nuclear reactors. Both provinces, though, have signaled to the Canadian government their interest in deploying small modular reactors as part of an economic strategy and an effort to shift to cleaner forms of power.

Terrestrial Energy Inc., a company based near Toronto, is developing a 300-megawatt reactor that uses molten salt as a coolant and fuel. The Canadian government awarded the company 20 million Canadian dollars, equivalent to about \$16 million, in financing to help spur further

research. Terrestrial is hoping to have its first small reactors ready for deployment by the end of this decade, assuming that regulatory hurdles are cleared.

The outlook in Canada for small modular reactors has political support, with the federal government and four of the 10 provinces on board with deploying the technology. “They believe these technologies are important to them, for their economy and environmental ambitions,” said Simon Irish, chief executive of Terrestrial Energy.

Some say that small modular reactors and other new designs look good on paper but haven’t met real-world tests yet. “These are PowerPoint reactors,” said Mycle Schneider, a Paris-based nuclear-energy consultant who is often critical of the industry. “These are not existing full-scale designs. It’s very far from being detailed engineering.”

Even some supporters of nuclear power say small reactors using new designs are likely to cost more per megawatt than established designs that pack large capacity into a single plant.

“It’s a shame in my view because you’ve spent all this time, all these years” developing and testing the latest generation of big reactors, said George Borovas, head of the nuclear practice at the law firm Hunton Andrews Kurth. First-of-a-kind reactors typically suffer delays, and “it’s more expensive than you would think,” he said.

Terrestrial Energy is one of the three companies that Ontario Power Generation is working with in anticipation of adding small modular reactors at the Darlington Nuclear Generating Station, located 45 miles east of Toronto and currently capable of generating 3,500 megawatts, or enough to power two million homes. Ontario Power Generation, a utility owned by the provincial government, is in a separate joint venture with Seattle-based Ultra Safe Nuclear Corp., which is seeking a license to build and operate a 15-megawatt modular reactor in a town about 125 miles northwest of the capital, Ottawa.

Mr. Irish said the next step for Canada is for governments to make available more financing to help upstart companies in the small-reactor field. “This is important industrial technology for Canada, from a climate-change, jobs and economic perspective,” he said.

Canada’s natural-resources ministry acknowledged its financial role in documents making the case for nuclear power, especially next-generation, small reactors.

Governments at the national and regional level “have a role to play in sharing the risk and reducing the cost of capital,” the ministry said. “Without government support, the private sector may not make the necessary investments to set the stage for an SMR industry in Canada.” Mr. O’Regan, the natural-resources minister, told reporters in December that additional money could be made available in the annual budget plan for 2021. “We cannot afford to take anything off the table,” he said. “I see the world in a very pragmatic way.”

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