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HOW THE DOMESTIC NUCLEAR INDUSTRY BOOSTS LOCAL ECONOMIES, CURBS EMISSIONS, AND STRENGTHENS NATIONAL SECURITY

FIELD HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTEENTH CONGRESS

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HOW THE DOMESTIC NUCLEAR INDUSTRY BOOSTS LOCAL ECONOMIES, CURBS EMISSIONS, AND STRENGTHENS NATIONAL SECURITY

FRIDAY, MAY 3, 2019

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to notice, at 10:07 a.m., in the Shippingport Borough Municipal Building, 163 State Route 3016, Shippingport, Pennsylvania 15077, Hon. Conor Lamb [Chairman of the Subcommittee] presiding.

Present: Representatives Lamb, Stevens, Foster, and Casten.

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY
U.S. HOUSE OF REPRESENTATIVES
HEARING CHARTER

How the Domestic Nuclear Industry Boosts Local Economies, Curbs Emissions, and Strengthens National Security
Friday, May 3, 2019
10:00AM EST
Shippingport Borough Municipal Building in Shippingport, PA

PURPOSE

The overall purpose of the hearing is to recognize nuclear energy broadly for the role it plays as an emissions-free energy source and as a national security asset, as well as for the impact these plants have on local economies. A specific focus will be on research and development needs to extend the lifetime of currently operating nuclear plants. Many of the nuclear plants in Pennsylvania are now at risk of being permanently shut down, and there is state legislation under consideration to support nuclear energy sources in similar ways to other emissions-free sources.

WITNESSES

- **Dr. Pete Lyons** is a former DOE Assistant Secretary for Nuclear Energy and NRC Commissioner. He was nominated by President Obama and confirmed by the U.S. Senate as Assistant Secretary for Nuclear Energy on April 14, 2011. Before joining DOE, Dr. Lyons was appointed by President Bush as a Commissioner of the U.S. Nuclear Regulatory Commission, starting on January 25, 2005. He now consults on several corporate and laboratory boards, as well as assisting several international groups.

- **Admiral William Fallon** is retired from the United States Navy after a distinguished 40-year career of military and strategic leadership. He previously has held the positions of head of U.S. Central Command, U.S. Pacific Command, Presidential Envoy to Japan, and Vice Chief of the Navy. He currently serves on many defense boards and consults in Washington, D.C.

- **Ms. Tina M. Taylor** is Deputy Chief Nuclear Officer and Senior Director of Research and Development at the Electric Power Research Institute. She is responsible for a diverse portfolio of research addressing technically challenging issues facing nuclear power. Her team is responsible for work in the areas of maintenance, engineering,

equipment reliability, instrumentation and control, risk and safety management, chemistry, fuel, high and low-level waste, and decommissioning.

- **Dr. Jay Apt** is a Professor at the Tepper School of Business and Department of Engineering & Public Policy. He is also Co-Director of the Carnegie Mellon Electricity Industry Center. He is a Fellow of the American Association for the Advancement of Science. He received the NASA Distinguished Service Medal and the Metcalf Lifetime Achievement Award for significant contributions to engineering.

Emissions-Free Electricity and Climate Change

There are 98 nuclear reactors operating at power plants in the U.S. today that collectively generate almost 20 percent of the nation's electricity. These plants provide more than 55 percent of the nation's emissions-free electricity. That is almost three times as much as that currently generated by hydropower, more than three and a half times as much as that generated by wind, and more than 18 and a half times that generated by solar.[1] To achieve deep decarbonization by mid-century, several independent studies have determined that nuclear energy will likely need to be included as a significant portion of the U.S. energy portfolio.[2,3,4] A case study that shows how nuclear power impacts a nation's ability to meet its climate goals is Germany. In 2011, German leaders decided to phase out all of that country's nuclear power by 2022. Since then, nuclear generating capacity in the country has halved, and Germany relies more on coal. In the same period, Germany more than doubled its renewables capacity but even so, Germany is now expected to miss its 2020 emissions targets. Based on capacity factors of Germany's nuclear plants prior to the phase-out, Germany would have been able to meet its climate goals.[5]

Resiliency, Reliability, and Subsequent License Renewal

Nuclear plants can store two years of fuel on-site, and the U.S. nuclear industry has had a nationwide average capacity factor of 90% over the last 20 years.[6] Nuclear power plants are originally licensed to operate 40 years. The Nuclear Regulatory Commission has approved initial

[1] "Climate." Nuclear Energy Institute. https://nei.org/advantages/climate
[2] "Nuclear Power and the Paris Agreement." IAEA. https://www.iaea.org/sites/default/files/16/11/np-parisagreement.pdf
[3] "Nuclear for the Next Generation: Addressing Energy, Climate and Security Challenges." The Global Nexus Initiative. http://globalnexusinitiative.org/uncategorized/nuclear-power-for-the-next-generation/
[4] "The Future of Nuclear Energy in a Carbon-Constrained World." Massachusetts Institute of Technology. https://energy.mit.edu/wp-content/uploads/2018/09/The-Future-of-Nuclear-Energy-in-a-Carbon-Constrained-World.pdf
[5] "Germany to miss 2020 carbon dioxide emissions target because of nuclear closure policy." World Nuclear Association. https://www.world-nuclear.org/press/briefings/germany-to-miss-emissions-target-because-of-nuclea.aspx
[6] "Nuclear by the numbers." Nuclear Energy Institute. https://nei.org/CorporateSite/media/filefolder/resources/fact-sheets/nuclear-by-the-numbers.pdf

license renewal applications for 94 reactors in the U.S.[7] This would extend the life of the plant from 40 to 60 years. There are currently six reactors in the U.S. that have submitted subsequent license renewal applications to the Nuclear Regulatory Commission which, if approved, would extend the period of operation from 60 to 80 years. The Nuclear Regulatory Commission utilizes research on aging plants and applies a rigorous review of applicant aging management programs before granting approval.[8]

Jobs and Contributions to the Economy

Each nuclear power plant employs 400 to 700 workers. Nuclear worker salaries are 36 percent higher than the average local salary.[9] The U.S. civil nuclear industry consists not only of the current fleet of operating nuclear power plants, but also the fleet of research and test reactors at national labs and academic institutions and the private industry working on furthering advanced reactor concepts. Various types of skillsets are needed in this workforce, not just nuclear engineers. Electricians, welders, sheet metal workers, operators, scientists, accountants, and many more other professionals are required. Expanding the scope of the industry to include the military, the required workforce further increases.

National Security

Military leaders have stated that a strong domestic nuclear industry is essential to U.S. national security not only to strengthen national competitiveness but also to maintain influence and leadership over nuclear safety and nuclear nonproliferation worldwide.[10] The nuclear workforce is shared between the civil nuclear industry and the nuclear military sector. Each benefit from the other in terms of workforce, technology innovation, and procurement pipelines. The more civil nuclear power plants that close, the more vendors such as fuel facilities will likely shut down, which would adversely affect this shared supply chain between the civil program and the military.[10] The Department of Defense is currently considering using micro-reactors to increase the energy reliability of the nation's defense installations.[11]

Other countries are making significant progress in advancing their nuclear industries both domestically and through exporting nuclear technologies. Russia has six reactors under construction today and has begun operating five reactors in the past five years. There are

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[7] "U.S. Nuclear License Renewal Filings." Nuclear Energy Institute. https://nei.org/resources/statistics/us-nuclear-license-renewal-filings
[8] "Status of Subsequent License Renewal Applications." U.S. Nuclear Regulatory Commission. https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html
[9] "Jobs." Nuclear Energy Institute. https://nei.org/advantages/jobs
[10] "Nuclear Energy, Naval Propulsion, and National Security." Center for Strategic and International Studies. https://www.csis.org/events/nuclear-energy-naval-propulsion-and-national-security
[11] "Input on a Pilot Program for Micro-Reactor Demonstration." USDOE. https://www.id.energy.gov/MICRO-REACTOR_REQUEST_FOR_INFORMATION%20Final.doc

currently 17 reactors of Russian design under construction globally. China has 13 plants under construction domestically and has begun operating 26 reactors in the past five years. There are currently 12 reactors of Chinese design under construction globally.[12] For comparison, the U.S. has two plants under construction domestically and has brought only one online in the past five years. The U.S. is not currently building any reactors abroad, while China and Russia are quickly becoming major players in supplying the rest of the world with nuclear technology.

Premature Plant Closures

In the past six years, seven nuclear reactors have been prematurely closed, mostly due to non-competitive economics versus other generation types. Cheap natural gas prices and disparity among subsidies that renewables are currently able to qualify for versus those for nuclear power contribute to premature plant closures. There are currently 12 reactors that have been announced to shut down in the next six years. For example, the nine nuclear reactors in Pennsylvania are at risk of premature closure, and three of these have been announced to shut down in the next two years.[3] These nine reactors produce almost 40 percent of the state's electricity and 92 percent of the state's carbon-free electricity. According to the Nuclear Energy Institute, these plants prevent more than 37 million metric tons of CO_2 emissions per year, which is equivalent to what 8 million passenger cars would release, more than double the number of registered cars in the state.[13] A study by the Brattle Group found that the retirement of all five Pennsylvania nuclear plants would result in a Pennsylvania GDP loss of $2 billion annually, with employment (direct and indirect) declining by 15,900 jobs.[14]

Twelve reactors have been saved from premature closure in the past few years in New York, Illinois, New Jersey, and Connecticut. The driver that saved these plants from closing early was state policy intervention. Currently, the Pennsylvania State Legislature is considering two bills (House Bill 11 and Senate Bill 510) that would provide support to keep the plants in Pennsylvania open.

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[12] "National Security." Nuclear Energy Institute. https://nei.org/advantages/national-security
[13] "Pennsylvania and nuclear energy." Nuclear Energy Institute. https://www.nei.org/CorporateSite/media/filefolder/resources/fact-sheets/state-fact-sheets/Pennsylvania-State-Fact-Sheet.pdf
[14] "Impacts of Announced Nuclear Retirements in Ohio and Pennsylvania." The Brattle Group. https://d3n8a8pro7vhmx.cloudfront.net/nuclearmatters/pages/313/attachments/original/1523484599/Impacts_of_Premature_Nuclear_Retirements_in_Ohio_and_Pennsylvania..pdf?1523484599

Chairman LAMB. All right. This hearing will come to order. Without objection, the Chair is authorized to declare recess at any time.

Good morning to everybody, and welcome to today's hearing, which is called, "How the Domestic Nuclear Industry Boosts Local Economies, Curbs Emissions, and Strengthens National Security."

I am Representative Conor Lamb of Pennsylvania's 17th District covering Beaver County, where we are now. And I'd like to begin first by welcoming all of the guests who have traveled here from outside of western Pennsylvania to visit us today. We are lucky to have several of my colleagues from the Committee on Science, Space, and Technology, who will introduce themselves and talk a little bit about their districts as you go on, but they come from the great States of Illinois and Michigan. I want to thank you for taking the time to visit us here and learn about our local nuclear power issues.

I also really want to thank our witnesses, who we are going to introduce individually as well, and you'll be hearing a lot from them today. But they have devoted their immense intellectual resources and energies to this problem that affects us and hits us really close to home here. So on behalf of all the people that I represent, especially here in Beaver County but really all over western Pennsylvania, I just want to thank all of you for taking an interest in us and spending some time here today.

I also want to recognize we have two of our local government officials with us here, Commissioners Dan Camp and Tony Amadio from Beaver County, who have done a lot to fight for the people working at this plant and all over Beaver County, and we're happy that you were able to take time to be with us today.

We have represented as well some of our State officeholders. I know State Representative Rob Matzie, who's an active member of the Nuclear Caucus in Harrisburg, would love to be here, and he has done a lot to carry the fight for you in Harrisburg, so I just want to recognize his work. And we have a representative from—State Senator Elder Vogel as well, who is in the trenches with us on this one. And we really appreciate their efforts and their ability to follow us here today.

We also have several of our tradesmen and women from IBEW's (International Brotherhood of Electrical Workers) Local 712 and 29, and I really want to thank them for taking some time. We have a representative of the painters' union, and it's very good of you to come here and remind us all that at the heart of all this are the jobs that are providing for families here in Beaver County and outside of it. Really all over the region, tradesmen and women come and they operate and maintain and upgrade this plant, and we have to always remember that.

Where we are right now today—we're holding this hearing here because we're in the shadow of the first-ever civilian nuclear power plant in the United States. That started right here in western Pennsylvania. And I think it's very important for us to remember that there was a time in World War II and shortly after where we were bold and adventurous enough to do something that, at that time, people actually thought was impossible.

No one would have believed just a few years before this place was built that it was possible to take a weapon of war, which is

how people thought of nuclear energy, and turn it into an instrument of peace. But President Eisenhower knew that that could be done. He knew that it had to be done. And I think we should all feel an immense pride as western Pennsylvanians that when it came time to do this, President Eisenhower chose Shippingport here in Beaver County for that project.

A lot of people know that Pittsburgh was already famous for contributing to the war effort through the steel industry, but not a lot of people know that we are the leaders in nuclear power as well. And it's amazing. I think in some ways we can feel even more pride about our nuclear heritage because, you know, steel came in large ways because we had things in the ground in western Pennsylvania that nobody else had, and we had a river system and all that kind of thing. The nuclear industry, it wasn't because of something specific that we only had here.

But I think President Eisenhower knew about the power of our scientific and research community, as represented by the Bettis Atomic Power Lab, and our incredible businesses Duquesne Light and Westinghouse, and most importantly, the abilities and courage of our people. They knew that they could get the job done. So that's why I think many of us are so proud.

When this first started in the 1950s, people were very uneasy about the idea of civilian nuclear power in their backyard, and I read that they actually—people were asking whether their lightbulbs would burn twice as bright in their homes once the power started coming from nuclear energy because they just thought it was that scary and powerful. But people took the risk here anyway. And what is incredible is since then, since construction began, I believe, in 1954, generations of members of the same families of hardworking tradesmen and woman, of engineers, of scientists, of nuclear officers have worked to not only maintain these plants but to upgrade them, rebuild them.

And now, the Beaver Valley Nuclear Station that has replaced Shippingport, it's one of the safest and most reliable power plants of anywhere in the world. It regular score—regularly scores among the tops in Pennsylvania and in the country, and that is solely due to the dedication and professionalism of the men and women that work there. And we got a chance to see that on our way here today. I want to thank the FirstEnergy folks for taking us on such a great tour and for doing such an amazing job running that plant.

Unfortunately, today, times have changed a little bit compared to the 1950s and 1960s when this all got underway, and the Beaver Valley Station, many of you know, is scheduled to close in 2021 if we don't do something. And I want to repeat that. It's not just at risk of closing; it is scheduled to close.

There are many reasons for that, but the fact remains that those thousands and thousands of people that worked so hard to build this industry here in our backyard, who worked so hard to provide power for all of us, provide for their own families, and contribute to the national security of this country, they deserve a lot better than to see their life's work go under in just a couple short years when that's avoidable. That does not have to be the outcome.

And I think right now that their work has never been more important. See, the electricity that is produced at Beaver Valley is

completely carbon-free. And because of the nuclear industry in Pennsylvania, we actually get 40 percent of our power across the State from nuclear energy, carbon-free power, 40 percent. It makes us a leader in the United States. I'm always struck by the fact that many of our friends and neighbors don't know that, that we—that this nuclear industry is such a huge part of our economy and that we're already getting 40 percent of our power carbon-free because of its contribution.

If we allow these plants to go under, a lot of that power, if not all of it, will be replaced by fossil fuels. We will never reach our goals when it comes to the climate and the environment if we allow nuclear energy to collapse.

The reason I talked about President Eisenhower today—and if you look over to the right here, you're going to see a picture of him waving this magic wand when they started construction of the power plant. He was so proud that this was his baby, this was his darling, that he supervised the construction of it from beginning to end. He is remembered for that level of focus and attention to detail in winning the war in World War II and then preserving the peace and building our national infrastructure like this plant.

And back then, people knew that all those things were related, and that's what we're going to talk about here today, how it's not just about the local economy and local power, but it's about the national security of the entire United States why we have to preserve this industry.

And I think if we could bring President Eisenhower back today and ask him how he would address the challenges of the 21st century after he was so successful meeting the challenges of the 20th, I think he would recognize them and he would say you've got to build and preserve this infrastructure again. You've got to renew it for a new century and new challenges like climate change and that we cannot afford to let these things go under.

So that's why we're really here today. We're here to talk about how we protect these jobs for our tradesmen and women, for our veterans. So many of the employees in the nuclear industry are veterans of the U.S. Navy's nuclear program, for our scientists.

And finally, the issue that we'll touch on in a little more detail is how there are going to be many nuclear power plants built overseas in the decades to come. There's about a billion people in the world today that still don't have electricity. And when our competitor nations like Russia and China look at that fact, they see a market. They see a market where hundreds of billions if not trillions of dollars to build these plants, to make all the parts that supply them, to send their scientists and people overseas to build them, the United States used think that way.

We used to go overseas and share our technology. In fact, there were people from the Shippingport plant here that went to Japan in the 1960s to help them build their nuclear power. That is world leadership, and that's making sure that this technology is done right. We can get back to that way of thinking again. There's no way that we can't. But there's a lot that we need to do. So that's what we're here to talk about today.

[The prepared statement of Chairman Lamb follows:]

U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY

Opening Statement

Chairman Conor Lamb (D-PA)
of the Subcommittee on Energy

Energy Subcommittee Field Hearing:
How the Domestic Nuclear Industry Boosts Local Economies, Curbs Emissions, and Strengthens National Security
May 3, 2019

I'll begin by welcoming all of our guests to Western Pennsylvania. We are lucky to have several of my colleagues from the Committee on Science, Space and Technology and as the hearing goes on you'll hear more about them and their districts in the great states of Illinois, Michigan, Texas and California. I just want to say thank you for taking the time to visit us here and learn more about our role in nuclear power.

I also want to thank our witnesses, who we will introduce individually, for taking the time to be with us and for devoting your energy to this subject. On behalf of the people I represent, especially here in Beaver County but all over Western Pennsylvania, I thank you for your interest in this issue that hits so close to home for us.

We are holding this hearing in the shadow of America's first civilian nuclear plant and we're doing that for a reason. It's time for us to remember that it wasn't so long ago we were bold and adventurous enough to do something that people thought was impossible — make nuclear energy into an instrument of peace rather than a weapon of war.

President Eisenhower knew this could be done — knew it had to be done — and I think all the Western Pennsylvanians in the room feel an immense pride that he picked us to build the first plant. A lot of people know about the role that Pittsburgh's steelworkers played in the war effort but our leading role in nuclear power isn't as well known. But it should be, because it didn't have to be us. President Eisenhower didn't build the reactor here because of something that we had in the ground that no one else had. He picked us because of great businesses like Duquesne Light and Westinghouse, and because of the work ethic and courage of our people.

People were uneasy — afraid about nuclear power — a lot of towns would have said no. The people of Western Pennsylvania said yes, and they have worked hard to provide safe, reliable nuclear power ever since. In fact, our workers have constantly upgraded this plant to the point where it is now considered one of the safest nuclear plants in the United States.

But times have changed, and today the power station that replaced Shippingport — Beaver Valley, which we toured — is scheduled to close in 2021 if something isn't done. Not at risk — scheduled. There are many reasons, but the fact is this: thousands of people worked hard to

build, maintain and operate this plant. Many of those thousands are veterans of our armed forces. They deserve better than to have their life's work pass into history, especially because their work has never been more important.

See — the people who make this plant run allow us to get electricity without emitting any carbon. In Pennsylvania, 40 percent of our electrical power is supplied by nuclear plants. A lot of people don't know that, but we're going to make sure people know it. 40 percent. We will never make progress on climate change without saving these plants and keeping these workers at work.

President Eisenhower is remembered for winning the war, keeping the peace, and building our national infrastructure. All of these things are related and they helped us lead the world in the 20th century.

If we could ask President Eisenhower about the great challenges of the 21st century, I think he would recognize them and tell us that this critical infrastructure — built and run by thousands of hardworking Americans here in Pennsylvania — is as critical today as ever. We have to protect ourselves and our children from climate change and to do that we need nuclear. We have to protect jobs for tradesmen and women, for veterans, for scientists, to have a strong country. And when foreign countries go to build nuclear plants — which they will — we have to have them turn to us instead of our adversaries.

Chairman LAMB. If there are any Members who wish to add their own additional opening statements to the record, you can do so at this point.

[The prepared statement of Chairwoman Johnson follows:]

U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY

Opening Statement

Chairwoman Eddie Bernice Johnson (D-TX)

Energy Subcommittee Field Hearing:
How the Domestic Nuclear Industry Boosts Local Economies, Curbs Emissions, and Strengthens National Security
May 3, 2019

Good morning and thank you, Chairman Lamb, for bringing together such a distinguished group of witnesses, and in beautiful Shippingport, Pennsylvania no less. This morning, I am excited to discuss nuclear energy's importance to our local economies, national security, and our fight against climate change.

Nuclear energy is a major pillar U.S. clean energy production today. Generating 20% of our nation's electricity, the civilian nuclear fleet is a large driver of the U.S.'s emerging clean energy economy. In addition to its carbon free emissions, nuclear power plants generate electricity at all times of day, currently providing reliable energy when other clean energy sources cannot. We must take advantage of these critical resources if we are to halt climate change and grow our economy.

Each nuclear power plant employs hundreds of high-paying jobs, whose salaries are often significantly higher than the average local salary. This directly supports families, schools, and local governments across the country. Moreover, these jobs are often located in rural areas, and are the bedrock of communities' local economies.

And not only are nuclear power plants important to local economies, but they are integral to our national security. Our armed forces rely on specialized equipment, engineers, and scientists to run and maintain nuclear technologies across the military. Whether it's powering a nuclear submarine, or maintaining the reliability of our nuclear weapons, the domestic nuclear energy industry ensures a strong supply chain and workforce for our military's nuclear needs. A strong domestic industry also allows the U.S. to remain a global leader in nuclear standards and non-proliferation.

Given its great value, I am troubled to see nuclear plants across the country struggle due to non-competitive factors. We cannot afford to lose the clean energy, jobs, and global security that nuclear power provides. We must ensure that the true life-cycle value of nuclear energy is recognized, and that Congress gives the nuclear industry the tools to continue innovating. I am excited to hear from our esteemed panel of witnesses, so that we can explore this important topic further.

With that, I yield back.

Chairman LAMB. Not seeing any, I would like to introduce our witnesses so everyone knows who we have with us today. And we are extremely lucky to have this panel with us.

So I'll start with Dr. Pete Lyons, who is a former Department of Energy (DOE) Assistant Secretary for Nuclear Energy and also a former Commissioner at the Nuclear Regulatory Commission (NRC). He was nominated by President Obama and confirmed by the Senate as Assistant Secretary for Nuclear Energy in 2011. Before being at the Department of Energy, Dr. Lyons was appointed by President Bush as a Commissioner at the Nuclear Regulatory Commission in 2005, so he's served under multiple Administrations. He now consults on several corporate and laboratory boards, and he assists several international groups. We're very thankful to him for traveling all the way from Colorado to be with us here today.

Next to Dr. Lyons we had Admiral William Fallon, who is retired from the United States Navy after a 40-year career of military and strategic leadership. He has previously held the positions of the Commander of U.S. Central Command and U.S. Pacific Command, Presidential Envoy to Japan, and Vice Chief of the Navy. I believe he was Vice Chief of the Navy on September 11th, 2001, and personally led some of the response that our Nation had on that day and afterward. He currently serves on many defense boards and consults in Washington, D.C., and we're incredibly thankful to have him with us today as well.

Next to Admiral Fallon is Ms. Tina Taylor, who is the Deputy Chief Nuclear Officer and Senior Director of Research and Development at the Electric Power Research Institute. She is responsible for a wide array of research addressing the most technically challenging issues facing nuclear power, and her team is responsible for work in the areas of maintenance, engineering, equipment reliability, instrumentation and control, risk and safety management. All the things that make these nuclear power plants actually work and be safe, Ms. Taylor can talk to us about today, including what it takes to decommission some of these plants.

Next to Ms. Taylor is a hometown boy, Dr. Jay Apt, who's a Professor at the Tepper School of Business and Department of Engineering and Public Policy at Carnegie Mellon University. He is also the Co-Director of the Carnegie Mellon Electricity Industry Center, which is actually one of the world's largest engineering business centers focused on the electric industry. He's a fellow of the American Association for the Advancement of Science. He received the National—the NASA (National Aeronautics and Space Administration) Distinguished Service Medal and the Metcalf Lifetime Achievement Award for significant contributions to engineering. He's also an astronaut by trade and will be talking about a wide array of things as they relate to nuclear power for us today.

So, as our witnesses should know, you will each have 5 minutes for your spoken testimony. Your written testimony has already been included in the record of this hearing, and when you have completed your spoken testimony, we will begin with questions from the Members. We will probably do multiple 5-minute rounds of questions, so you'll have a chance to share everything that you

have to share with us today. Again, I'm just incredibly thankful to have you here with us, and we will start now with Dr. Pete Lyons.

TESTIMONY OF DR. PETER LYONS, RETIRED DOE ASSISTANT SECRETARY FOR NUCLEAR ENERGY, AND FORMER NRC COMMISSIONER

Dr. LYONS. Thank you, Chairman Lamb, and also Representatives Stevens, Foster, and Casten. It's really an honor to testify in today's hearing.

As you just heard, I retired as the Assistant Secretary for Nuclear Energy after prior service as Commissioner of the Nuclear Regulatory Commission and also many years as a Science Advisor on U.S. Senate staff. I also held many positions at Los Alamos National Laboratory in many decades there. In retirement, I've co-chaired the American Nuclear Society's Committee on Nuclear in the States, which published a toolkit to provide States with options to protect their nuclear plants. We also published the "U.S. without Nuclear Energy, a Report on the Public Impact of Plant Closures."

I now serve as the Subcommittee Co-Chairman for the Energy Department's Nuclear Energy Advisory Committee. Their recent recommendation from that subcommittee was that policy changes are essential to ensure survival of the existing fleet of the U.S. commercial nuclear plants.

Our nuclear power plants, the most resilient component of our Nation's electrical grid, represent a vital national resource. Former Governor Ridge has said that the goal of grid reliance cannot be met without nuclear power. When the 18-month fuel supply at a typical nuclear plant is contrasted with needs for constant coal shipments or operating gas pipelines, the role of nuclear power is simply beyond question. They provide confidence that power will be available as needed. They also contribute nationally about $2 billion in State taxes, $10 billion in Federal taxes, and add about $60 billion to the Nation's GDP.

In 2018, the national average for nuclear generation cost was 3.2 cents per kilowatt hour, very low. But even that low price isn't always sufficient for profitability when nuclear energy's attributes are not compensated by electricity market structures. Low gas prices are impacting economic sustainability of nuclear power plants, and State mandates for intermittent renewable energy plus Federal and State tax credits for renewables have further undermined the economics of nuclear power.

These factors are leading some nuclear plants to close. More early closures could force closure of all—I say all our nuclear power plants. Closure of nuclear plants, as you said, increases fossil fuel use and emissions. Nuclear plants provide more than half of our Nation's emission-free electricity, enabling clean air and addressing climate change. Energy Secretary Perry has said, "I don't know how anybody who cares about the climate can't speak for nuclear energy."

In Pennsylvania, your nuclear plants provide 42 percent of your electricity and about 94 percent of your clean energy. There are 5,000 workers in your nuclear plants with over 500 companies in Pennsylvania supporting the nuclear industry. Your Governor issued an order to slash emissions. If your plants close, that won't

happen, and Pennsylvania would be transformed from a power exporter to a power importer. Your Nuclear Energy Caucus reported that your nuclear plants reduced annual electric bills in Pennsylvania by about $800 million.

Unfortunately, whenever preservation of nuclear power assets is discussed, it's fought by natural gas and sometimes by renewable companies, despite the fact that a diverse energy supply is absolutely vital to consumers. When these groups argue against nuclear power, in my mind, they are certainly not arguing in the best interest of the public.

Fuel diversity is an essential, necessary requirement for a stable grid. Former Governor Ridge noted, "Only an electric grid built on diverse and stable sources of energy can withstand evolving threats and make sure the lights stay on."

Our nuclear power plants also provide vital national security benefits. Our nuclear navy and weapons programs are supported by the infrastructure of nuclear power. In addition, when U.S. companies export their designs and expertise, they also export U.S. safety and nonproliferation standards. But now, international construction is being dominated by Russia and China, so they will be setting future international safety and nonproliferation norms, and the U.S. loses influence and jobs.

Pennsylvania legislators are considering two important bills to preserve your nuclear power. As one deeply concerned about the energy future we leave for our children and grandchildren, it's my sincere hope that the ideas in these bills enable a future for nuclear energy in Pennsylvania.

Thank you.

[The prepared statement of Dr. Lyons follows:]

Testimony
Dr. Peter B. Lyons
to the
Subcommittee on Energy of the House Science, Space and Technology Committee
Field Hearing
May 3, 2019
Shippingport, Pennsylvania

Chairman Lamb, it is an honor to testify in this field hearing of your Subcommittee on Energy of the House Science, Space, and Technology Committee. I compliment your strong support for Pennsylvania's nuclear plants. I concur in your position and hope my testimony today expands on my rationale.

By way of introduction, my recent government service was as President Obama's Senate-confirmed nominee for the position of Assistant Secretary of the Department of Energy for Nuclear Energy, a position I held for more than four years. Prior to that, I was appointed by President George W. Bush and subsequently nominated by him and Senate-confirmed to serve one five-year term as a Commissioner of the U.S. Nuclear Regulatory Commission. That service followed eight years as Science Advisor to the U.S. Senate Energy and Natural Resources Committee and U.S. Senator Pete Domenici. I also served in many research and management positions at Los Alamos National Laboratory after my 1969 graduation from the California Institute of Technology.

Since my retirement in 2015, I have been active in many activities related to preserving the vital resource represented by the nation's nuclear power plants. I served as co-chairman of the American Nuclear Society's Special Committee on Nuclear in the States. In addition to helping in New York and Illinois, as they were some of the first states to consider development of legislative initiatives to prevent potential nuclear plant closures, the Special Committee published two documents that have been widely cited. One was "The U.S. without Nuclear Energy: A Report on the Public Impact of Plant Closures," and the other was a "Toolkit" designed to provide states with a menu of potential actions that could be taken to protect their nuclear power plants. In addition, I serve on the Advocacy Council of Nuclear Matters. And, more recently, I accepted the role as Co-chairman of the Subcommittee on the Existing Fleet for the U.S. Department of Energy Nuclear Energy Advisory Committee or NEAC. The Subcommittee's report on the sustainability of the existing fleet was accepted as a NEAC document and approved for public release in late March. The "Key Recommendation" of that report was that "Policy changes are necessary to assure survival of the existing fleet of U.S. commercial nuclear plants." Such changes could occur at the state or federal level; either way, they are essential!

When I served at the NRC, we were focused on planning for a potential "nuclear renaissance," a rapid growth in nuclear power that was widely anticipated. Even when I started at the DOE, the magnitude of the impact of low-cost shale gas was not yet appreciated. When fracking began to sharply reduce the prices of natural gas, my first inclination was to remember the past instabilities in those prices and assume they would soon increase. But here in Pennsylvania, you are enjoying a remarkable boom in production of that gas that has proved to be of tremendous economic benefit to your State and the nation. Furthermore, any forecasts for the future price of natural gas reflect its sustained abundance and provide assurance that the price of natural gas will remain very low far into the future.

The low prices for natural gas are one key factor that has impacted profitability of many of the nation's nuclear power plants. That factor and many state mandates for use of intermittent renewable energy, along with federal and state tax benefits for renewables, have also complicated the sustainability of nuclear power in the United States. Today, we have seen several premature nuclear plant closures, long before the end of their licensed operation, and more plants have announced plans to close, including some of the plants in Pennsylvania. The NEAC Report noted that this trend toward early closures, if not arrested, could lead to a point in time when the remaining nuclear plants in the United States view their ability to maintain the requisite infrastructure for nuclear energy as unsustainable. This could precipitate a loss of our entire nuclear power industry. And in every case, here in the United States as well as abroad, when nuclear plants have closed, the use of fossil fuels has increased with a concomitant increase in greenhouse gas emissions.

Our nuclear power plants represent a vital resource for the nation. They are by far the most resilient component of our nation's electrical grid, as has been proven in some of the extreme weather events in the last few years. Pennsylvania has certainly experienced some of these severe events and your former Governor Tom Ridge noted in a 2017 editorial that the polar vortex of 2014 posed a serious threat to Pennsylvania's electrical grid. He stated, "Forty thousand megawatts of forced outages almost plunged the Northeastern and Midwestern United States into darkness." He also wrote in that same editorial that "The goal of grid resilience cannot be met without nuclear power."

Earlier this year, another record cold snap hit Pennsylvania such that electricity demand within this region came within a very few percent of setting a record for electricity demand. Pennsylvania citizens should be most appreciative that in the January 2019 polar vortex, all of Exelon's Pennsylvania nuclear plants operated at full power while wind chill factors went as low as minus 35 Fahrenheit. Former Governor Ridge also noted in April of this year that "Despite the abundance of natural gas from shale deposits that has done so much for the Commonwealth's economy, we still must maintain diverse energy supplies to prevent us from becoming overly dependent on any one source." A related important point is that electricity prices from some sources skyrocket on very cold days, with a recent example topping a 500 percent increase for New England customers, while the cost of generation for nuclear power stays quite constant.

When the 18-24-month fuel supply on-site at a nuclear plant is contrasted with the need for continued shipment of coal or operation of gas pipelines to run fossil fuel plants, the vital role of nuclear power plants in resilience of the grid is beyond question. The high capacity factors for nuclear plants, averaging over 92% across the country in 2018, provide superb reliability and give confidence to consumers that the plants will be providing power when they need it. They also contributed over $2B in state taxes and about $10B in federal taxes, and the broader nuclear energy sector in the U.S. supports almost 500,000 jobs. Estimates are that the nation's nuclear power plants add about $60B to the nation's GDP.

The carbon-free generation of electricity by nuclear plants is critical as clean air and mitigation of climate change are increasingly valued. In fact, nuclear plants provide more than half of the nation's emissions-free electricity. An interesting statement from Secretary Perry at a conference in March, coming from an Administration that does not agree with the threat of climate change, was: "I don't know how anybody who cares about the climate can't be for nuclear energy."

Pennsylvania's nine nuclear power plants provide about 42% of the State's electricity and provide an extremely high percentage of your clean energy, around 94%. In Pennsylvania, the capacity factors for the State's nuclear plants, averaged over the last three years, exceeded the national average by a significant amount at 96%. There are about 5000 workers in Pennsylvania's nuclear plants, with over 500 Pennsylvania companies supporting the nuclear industry. And the Governor of Pennsylvania has issued an executive order, setting goals to slash the State's emissions by 26% by 2025 and 80 percent by 2050. That won't be accomplished with closure of Pennsylvania's nuclear power plants.

A recent report of The Brattle Group titled "Pennsylvania Nuclear Power Plants' Contribution to the State Economy" noted that: "Absent the energy from these nuclear plants, Pennsylvania would need to rely more heavily on natural gas and coal-fired generating plants, many of which are outside Pennsylvania. Pennsylvania would be transformed from a substantial net exporter of power to an importer." Pennsylvania's bipartisan Nuclear Energy Caucus reported in late 2018 that the state's nuclear plants moderated electricity prices, benefitting Pennsylvania customers by an estimated $788M per year in lower bills. Pennsylvania's nuclear plants pay about $69M in State tax revenues annually. In addition, your universities benefit from and contribute to your commercial nuclear plants. Pennsylvania's educational resources for nuclear power include some of the nation's leading programs. The University of Pennsylvania, University of Pittsburgh, Carnegie-Mellon University, Penn State University, and others provide the State with immense intellectual capacity for nuclear issues, and they will be negatively impacted if Pennsylvania's nuclear plants close.

By any standard, nuclear power demonstrates impressive economics. In 2018, the average generation cost for U.S. nuclear power plants was about 3.2 cents per kWh. That figure results from a continued focus on improved economics. For example, by comparison, in 2012 the average cost for U.S. nuclear power was 4.2 cents per kWh. (However, these impressive averages obscure some details, such as higher costs for operating single-unit sites as opposed to multi-unit sites.) While further economies are being sought, the situation remains complicated by the very low generation costs for natural gas and by the fact that intermittent solar and wind operate with zero fuel cost, solar construction costs are reduced by federal investment tax credits, and wind farms (and some solar installations) earn federal production tax credits whenever they operate. The federal tax credits and other policy incentives provided to solar and wind mean that they can profitably run even when their abundance in some locations and at some times of the day leads to negative electricity prices. Obviously, no energy source that purchases its fuel can compete at negative pricing. But since consumers need electricity when the sun and wind do not cooperate, other sources of power must be standing by to provide power as needed.

The NEAC Report also noted the unfortunate trend, which is also happening in Pennsylvania, that whenever preservation of nuclear power assets is discussed in a state legislature, that preservation is fought by natural gas companies and, all too frequently, also by companies selling renewables. We noted appreciation in the NEAC Report that Secretary of Energy Rick Perry has stated that the grid is too reliant on natural gas and we even suggested that the Secretary be still more vocal in addressing such attacks against nuclear power. There can be no question that a diverse energy supply is of monumental importance to consumers. Any energy sources can experience problems, although nuclear energy is the least likely of any large energy source to experience an interruption, and it is vital that the citizens are protected from any lapses in generation In my opinion, when natural gas and renewable interests argue against nuclear power, they are certainly not arguing in the best interests of the citizens.

Fuel diversity is simply a logical and necessary requirement for a stable grid. Any statement to the contrary is inviting an energy and economic disaster for the country. It is instructive to note that the two most recent Secretaries of Energy have each echoed the need for an "all-of-the-above" energy strategy. Former Secretary Ernest Moniz used this phrase frequently as he discussed the need to strive towards cleaner energy options through a diverse set of sources. And Secretary Perry stated a few months ago that "I don't believe in putting all your eggs in one basket. Right now, the gas industry is a fabulous blessing, and thank God that we have it. But it's the ability to have a resilient grid, a reliable supply of energy, that I think is tantamount to our national security." Former Governor Ridge also addressed fuel diversity in his April 2019 editorial when he stated, "Only an electric grid built on diverse and stable sources of energy can withstand evolving threats ... and make sure the lights stay on."

Nevertheless, articles still appear claiming that a 100% renewables future is within our reach. When I see such statements, I can only laugh. No matter what time scale anyone proposes, in my view it is not realistic or possible. For example, when such an article appeared a few years ago, a group of 27 scientists wrote a paper with strong counter arguments. Papers making arguments for 100% renewables claim wonderful contributions from batteries coupled with renewables, but the simple fact is that no battery, available today or in the foreseeable future, could possibly power our grid in an economic way for long periods of time. (Depending on weather patterns, we could easily face days or even weeks without production from renewables!) Secretary Perry recently commented, "Is the money spent on keeping baseload worth it? I think it is." And even if any single source like renewables could theoretically power the country, the loss of fuel diversity should invalidate such speculation.

Many discussions of late have considered the so-called Green New Deal. It's interesting to see how other leaders have changed those words. In an editorial a few months ago, Dr. Moniz emphasized that "a wise and just transition to a low-carbon economy, moving as fast as is technically and socially possible" is needed; he called this a Green Real Deal. And when Secretary Perry spoke recently in Georgia at the construction site for two new nuclear plants, he stated, "Look around you, this is the real new green deal."

In that same editorial, Dr. Moniz recommended "looking hard at advanced nuclear technologies" in the essential transition to clean energy sources. He also emphasized that decarbonization of our overall energy system must extend far beyond the electricity sector, since the electricity sector emits only about 40% of the total carbon entering the atmosphere. There are many studies underway of innovative ways to extend the use of renewables and nuclear energy into the transportation and industrial sectors to help in this decarbonization effort. In that context, I devoted significant effort when I was Assistant Secretary to seek solutions for decarbonization across all energy sectors. Our nation can be powered with minimal carbon emissions if we transition to a future with only clean energy sources: renewables, fossil fuels with carbon capture or utilization, and nuclear power. There is a great deal of research, both in this country and abroad, now focused on developing paths that best utilize all these clean energy sources for significant decarbonization of the world's energy requirements.

The NEAC Report, of course, focused on national benefits and, from that perspective, the national security benefits of our nuclear power plants can not be understated. We quoted and strongly agreed with Secretary Perry who stated that "Energy security is national security." Certainly, the reliability and resilience contributed by nuclear power to our national grid are fundamental to our energy and national security. But the Report also quoted many studies noting that our nuclear navy and nuclear weapons

programs are supported by the infrastructure, including educational institutions, of the nation's nuclear power industry. The Report quoted a June 2018 letter to the Secretary of Energy from a group of 77 prominent Americans commending him "for recognizing the important role our civil nuclear energy sector plays in bolstering America's national security," and asking that he "continue to take concrete steps to ensure the national security attributes of U.S. nuclear power plants are properly recognized by policymakers and are valued in U.S. electricity markets." That letter was signed by a host of former leaders: 4 Senators; over 20 top military leaders; several White House officials; a number of Secretaries and other senior leaders from State, Defense, Energy, and Veterans Affairs; two Chairs of the Nuclear Regulatory Commission; 7 directors of national laboratories; and several Ambassadors.

The importance of the commercial nuclear energy industry was also recently noted in a report from the Energy Futures Initiative, whose President and CEO is Dr. Moniz. That report, "The U.S. Nuclear Energy Enterprise; A Key National Security Enabler," noted that "Nuclear power and a robust associated supply chain (equipment, services, people) are intimately connected with U.S. leadership in global nuclear nonproliferation policy and norms and with the nation's nuclear security capabilities." It also stated that "The U.S. nuclear navy relies on a robust domestic nuclear energy supply chain."

Another important point must be emphasized on the national benefits of the nation's nuclear power plants. In years past, the United States was the unquestioned leader in nuclear energy. Our exports of nuclear power provided the foundations for a large fraction of the nuclear plants around the world. When U.S. companies exported their designs and expertise, they also exported U.S. safety and nonproliferation standards. In addition, they created long-term, close to a century, relationships between the U.S. and other nations. Now Russia is, by far, the dominant international builder of nuclear power plants. China, while currently focused on building their own domestic plants, is beginning to explore significant international opportunities and, with high confidence, international construction of nuclear power plants will be dominated by Russia and China in the foreseeable future unless the U.S. nuclear industry is revitalized. If the U.S. loses its ability to compete on the international market, we cede those markets to Russia and China. At the same time, we will be ceding international leadership on safety and nonproliferation to Russia and China and those countries will build a century-long global dependence on their nuclear energy suppliers. Loss of domestic nuclear power plants seriously undercuts our international competitiveness with dangerous implications for national security.

I noted that you, Chairman Lamb, have discussed the possible closure of Pennsylvania nuclear power plants with Secretary Perry. The Secretary last March supported state initiatives to sustain their nuclear plants and has also proposed approaches for federal initiatives to accomplish this end. As I noted earlier, he has stated that the grid is too reliant on natural gas. I might note that the NEAC Report was strongly supportive of a range of federal initiatives that could help to address market failures that are undermining nuclear energy in this country. Such initiatives would sustain our vital nuclear power industry. But the Report also recognized that the only successful such measures to date have been at the state, not federal, level.

In preparing for this testimony, I studied the pioneering roles that Pennsylvania has played in our nation's energy development. I found reports developed by the Pennsylvania Historical and Museum Commission to be most informative. These reports described the wide range of energy sources that have shaped this State's and the nation's history. From the time of the earliest Native Americans in this area, residents have depended on the vast timber resources. In the early colonial days, wind-powered

sailing ships traveled on Lake Erie. Somewhat later, Pennsylvania's coal and charcoal fueled the State's blast furnaces and water-driven mills powered large mills. The first successful commercial oil well was near Titusville in 1859. And I noted interesting reports that long before 1859, as early as 1410, Native Americans were using that same oil for medicinal purposes and that early settlers used it as fuel for lamps. Most recently, your successes with fracking technology have revolutionized production of natural gas such that Pennsylvania is now the country's second largest producer of natural gas.

In nuclear energy, Pennsylvania has figured prominently in two of the technology's most important events, and the decision on pending State legislation to sustain Pennsylvania's nuclear plants may prove to be another such event. As folks here should know well, the era of commercial U.S. nuclear power began here with the 1957 operation of the Shippingport Atomic Power Station. Westinghouse Electric Company, the Duquesne Light company, and the Bettis Atomic Power Laboratory collaborated to construct that Power Station using a reactor core from a cancelled nuclear-powered aircraft carrier, under the overall guidance of Admiral Hyman Rickover, the father of the nuclear navy. That reactor operated until 1982. The State's role in our nuclear navy traces back even further, when collaboration of Westinghouse with Argonne National Laboratory for submarine power began in 1948...

The other defining event was the Three Mile Island accident. I traveled to TMI early in my NRC tenure to learn in detail about that accident. As you know, there were no health consequences from that accident, but the stress induced by the accident and the resultant evacuations certainly negatively impacted the public. That TMI visit helped to cement in my mind how the regulatory agency and the entire nuclear industry learned vital lessons on safety from that accident, which led to massive changes in NRC regulations and procedures. Those lessons have played a vital role in the superb safety record that nuclear plants have demonstrated in the United States ever since. The nation's current nuclear fleet owes an immense debt to the vital lessons learned from the TMI accident.

In closing, I want to comment on two pieces of legislation, HB 11 and SB 510, introduced in the Pennsylvania legislature by Representative Tom Mehaffie and Senator Ryan Aument, along with many co-sponsors. Those bills would recognize nuclear energy in the Pennsylvania Alternative Energy Portfolio Standards for its contribution to the State's zero-carbon energy production. These legislative proposals follow the general model of successful outcomes in Illinois, New York, and other states and incorporate approaches discussed in the American Nuclear Society's Toolkit that I described earlier

As one deeply concerned about our nation's energy future and the world we leave for our children and grandchildren, it is my sincere hope that the framework of these two legislative vehicles provides a basis for a favorable outcome for nuclear energy in Pennsylvania. With that outcome, Pennsylvania would join other states that have recognized and are preserving the benefits of nuclear power for future generations.

Peter B. Lyons

Dr. Peter B. Lyons retired from the Department of Energy on June 30, 2015. He now consults on several corporate and laboratory boards, as well as assisting several international groups. He was nominated by President Obama and confirmed by the U.S. Senate as Assistant Secretary for Nuclear Energy on April 14, 2011 after serving as Acting Assistant Secretary since November 2010. Dr. Lyons was appointed to his previous role as Principal Deputy Assistant Secretary of the Office of Nuclear Energy in September 2009.

Before joining DOE, Dr. Lyons was appointed by President Bush as a Commissioner of the U.S. Nuclear Regulatory Commission, starting on January 25, 2005. He was subsequently nominated by President Bush and confirmed by the U.S. Senate. His NRC term ended on June 30, 2009.

Previously, Dr. Lyons served as Science Advisor to U.S. Senator Pete Domenici (R-NM) and the Senate Committee on Energy and Natural Resources from 1997 to 2005. From 1969 to 2003, Dr. Lyons worked at the Los Alamos National Laboratory where he served on assignment to Senator Domenici, and as Director for Industrial Partnerships, Deputy Associate Director for Energy and Environment, Deputy Associate Director for Defense Research and Applications and Group Leader for Fast Plasma Diagnostics. While at Los Alamos, he spent over a decade supporting nuclear test diagnostics.

Dr. Lyons has presented more than 400 papers or talks on a wide range of technical and policy topics in addition to testifying before the U.S. Congress on many occasions. He holds four patents related to fiber optics and plasma diagnostics and served as chairman of the NATO Nuclear Effects Task Group for five years. He received his doctorate in nuclear astrophysics from the California Institute of Technology in 1969 and earned his undergraduate degree in physics and mathematics from the University of Arizona in 1964. Dr. Lyons is a Fellow of both the Ameri-can Nuclear Society and of the American Physical Society; received the Henry DeWolf Smyth Nuclear Statesman Award from the American Nuclear Society and the Nuclear Energy Institute, the Alvin M. Weinberg Medal from the American Nuclear Society, the James Landis Medal from the American Society of Mechanical Engineers, and a Lifetime Achievement Award from the Nuclear Infrastructure Council; and was elected to 16 years on the Los Alamos School Board.

Dr. Lyons grew up in Nevada and is now a resident of Golden, Colorado.

Chairman LAMB. Thank you, Dr. Lyons.
Admiral Fallon.

TESTIMONY OF ADMIRAL WILLIAM FALLON, RETIRED, UNITED STATES NAVY

Adm. FALLON. Mr. Chairman, Members of the Committee, it's a great pleasure and honor to be here, and I would appreciate my written testimony being entered into the record.

If I could, I'd just like to take a few minutes to share a couple of ideas with you. First, I'm here as a private citizen. I'm not in any way representing any of the industry folks whatsoever, but I do have 4 decades-plus of experience in the United States Navy, and much of that operating from an aviator in my distant past flying from aircraft carriers that were nuclear-powered for the last 30 or so years.

And I think it would be good for us to recall some things that went on back in those early days. You mentioned President Eisenhower, Mr. Chairman. You've got a mugshot of the President over here on the display board. When I was a young second-grader, I met him when he was running for office in 1952. I know that's why they call me the craggy Admiral. But I want to just give a perspective of those days.

And in the early 1950s when you talked about atomic anything, it was weapons. And this increasing threat of atomic war we had already used these weapons— remember the Russians had them, the Chinese had just acquired them—it was pervasive. Eisenhower had the vision and the drive to want to do something else, and he saw the potential of technology. The U.S. was developing options to actually use this what we call nuclear power, this atomic power, for other things, peaceful things because he knew the world needed help.

And one of the things every place in the world needed, this country and others, was electric power, and the potential to have nuclear energy turn into power was very appealing but needed a lot of development work. The United States Navy at the same time was thinking seriously about this.

So from my experience in the Navy I can tell you that the advent of nuclear power has given the U.S. Navy a phenomenal ability to operate in ways that it could only have dreamed about in the early days. It provides a tremendous opportunity to provide a deterrent, a strategic deterrent for this country in the form of our ballistic missile submarines that's just unequaled in the world. And our aircraft carriers, all of which are nuclear powered now, not only help in that deterrent but have a phenomenal striking capability should they be needed.

So just a little sea story, in 1980, I was on the aircraft carrier USS Dwight D. Eisenhower. We were deployed to the Indian Ocean, and we, for many reasons, ended up remaining at sea for 152 straight days, 5 months operating continuously, this feat has never been approached in terms of records back to World War II, and in fact it's only been broken once by another former flagship of mine. USS Theodore Roosevelt actually went to 160 days. But it's a lot of time at sea.

So tying things together, President Eisenhower came here and formally opened this plant. He had the vision. And since that time in the early days—by the way, did you know that the person that was in charge of design and construction of this facility here at Shippingport was the same person that was the father of the nuclear navy, Admiral Hyman Rickover. And Rickover was intentionally put in charge of this operation because he was the kind of guy that got stuff done. We could use him today I think to help us along.

But since those days, the Navy and the commercial nuclear industry have been intertwined in innumerable ways. And in fact that's the crux of the problem that I see today. The decline of the commercial side is severely affecting the U.S. Navy, and it's affecting our national security. The network of infrastructure that supports both the commercial and Navy side are difficult to distinguish. The supply chain that enables the operation of these plants—by the way, there are only about 200 nuclear reactors in our entire country. Half of those are on Navy ships and the other half, declining numbers, are in our commercial plants.

As someone already mentioned, the people that enable this industry to keep going and the people that enable our Navy to operate are often one and the same. And if you took a poll of people that are working in the commercial industry, you'd find an awful lot of Navy people. But we get people in the Navy, interestingly enough, because when people are young, they look down the road and they say, hey, what am I going to do, you know? I'm in the Navy 20, 25 years, and then what? The Navy and commercial nuclear share the people.

The situation today is not good. We are strategically ceding the initiative to—increasingly to Russia and China, as Congressman Lamb already mentioned. These two countries alone have under construction or in planning more than 200 nuclear power plants today. The United States, zero. The Russians have $130 billion of signed orders to build plants. We have not a penny, nothing. There's something wrong with this picture.

So let's go back to Eisenhower's idea. He had a vision. He thought that he could promote peace and stability, and the objectives of that program that he started and announced in a speech in front of the U.N., was known as the Atoms for Peace initiative, had three cornerstone ideas. One was to prevent the spread of nuclear weapons. How did that happen? Because Eisenhower—and, by the way, there was a lot of staff disagreement, a tremendous amount of angst in Washington, you better not do this, oh, it's dangerous, you're going to spread this technology, really bad, but he prevailed. He wanted to limit the spread of nuclear weapons because when the countries agreed to take that technology, they also had agreed to non proliferate.

Second thing, it enshrined the U.S. as the leader in—as Dr. Lyons already indicated, U.S. safety standards, U.S. procedures, U.S. technology in an agreed, regulated format that is certainly not the case with our adversaries in the world today.

And the third thing is it enabled this country to develop relationships with other countries that are longstanding, so these nuclear plants are built to last 50 to 100 years. For the duration of these

arrangements in other countries you need people working together, trusting one another, technology exchange. That's all disappearing now as we've just kind of walked away from this thing. So for these key reasons, I think that this country needs to really step back and do some serious thinking.

It isn't just about local clean energy, which ought to be very important to everybody. Solar, wind, nuclear are not the same. The sun doesn't shine 24 hours a day. The wind doesn't blow. But the 95 percent or better availability which nuclear power delivers, and I think it's something we need to consider. We need to use our heads. We need a balance. And this balance at the domestic local level is really important, but in the strategic international level for national security, it's really important, and we need to get back in the program in my opinion.

Thank you very much for the opportunity.

Chairman LAMB. Thank you, Admiral.

Adm. FALLON. I look forward to your questions.

[The prepared statement of Adm. Fallon follows:]

TESTIMONY OF

WILLIAM J. FALLON

ADMIRAL, U.S. NAVY (RETIRED)

U.S. House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Energy

Field Hearing on
How the Domestic Nuclear Industry Boosts Local Economies, Curbs Emissions, and Strengthens National Security

May 3, 2019
Shippingport, Pennsylvania

Committee Chairwoman Johnson, Subcommittee Chairman Lamb, Ranking Member Weber. Good morning. It is a pleasure to be here in Pennsylvania to testify about this important topic of commercial nuclear energy and the relationship to national security.

It is fitting that the hearing is taking place here in Shippingport, the site of the first commercial reactor in the world dedicated to peaceful use, generating electricity for citizens in this vicinity.

It was my honor to serve on active duty in the United States Navy for more than 40 years. There has been, and continues to be, a very close and interesting historical relationship between the U.S. Navy and the commercial nuclear power industry in this country.

The first nuclear powered vessel in the Navy, the submarine USS Nautilus was commissioned in 1955. President Dwight Eisenhower opened the Shippingport power plant in 1958. The reactors of both of these power plants were essentially the same and construction of both was overseen by the same person, then Captain, later Admiral, Hyman G. Rickover, U.S. Navy.

Since those early days of nuclear power, the Navy and the U.S. commercial industry have operated with many close connections and dependencies. Today, of the approximately U.S. 200 nuclear power plants in operation, half are in the Navy, most powering submarines and aircraft carriers. The Navy and the civil power sector share the same industrial base, supply chain and talent pool.

Nuclear power has been intrinsically tied with U.S. government interests and national security since it was first brought on line in the 1950s. But in recent years, a steady decline in the commercial nuclear energy sector threatens to undermine national security by diminishing our ability to exert geopolitical influence.

Today, particularly in strategic locations around the world (Middle East, Africa and Southeast Asia), competing powers Russia and China have aggressively moved to fill the void created by a diminished U.S. nuclear presence. The contraction of civil nuclear power has resulted in U.S. ceding world-wide nuclear leadership, eroding the industrial base for our Naval Nuclear Propulsion Program and diminishing the ability to fuel our ships (as we currently have no domestic fuel manufacturing capability).

Commercial nuclear power and the U.S. government share a long history that is intertwined with the global struggle for peace and democracy. In December of 1953, 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 not to use the technology to develop nuclear weapons. This program, known as "Atoms for Peace", had three important national security objectives:

--To prevent the spread of nuclear weapons

--Establishing the U.S. as the leader in nuclear power, thereby enshrining U.S. nuclear safety and security standards, nuclear technology development and nuclear trade

--Ensuring that the U.S. (and not Russia) benefitted from the geopolitical relationship that goes with such significant assistance with a foreign country's power supply

For decades, the U.S. led in nuclear power generation, with safety and security leadership at home and abroad. Regrettably, the U.S. no longer leads, as Russia and China now dominate nuclear power plant construction around the world, using it as a tool to exert foreign influence and achieve economic gain.

Russia today has a $130B book order for new foreign reactors. The U.S. has zero.

Russia and China, as a part of its Belt and Road initiative, have made it a priority to sell nuclear reactors abroad, increasing their spheres of influence and the energy dependence of host nations. And it is a highly profitable trade.

The struggling nuclear power industry in the U.S., now directly competing against foreign governments which heavily subsidize for new projects abroad, has been sidelined on the international stage.

The U.S. civil nuclear power program, launched simultaneously with the Naval Nuclear Power Program, with Admiral Rickover overseeing both, remain closely connected. But our Navy's technological readiness, fuel and strong talent pool are threatened by the decline in the commercial nuclear power industry.

Without staying ahead of technological advances, the Naval Nuclear Propulsion Program risks falling behind faster, stealthier and more powerful submarine and aircraft carrier designs from Russia and China. While the U.S. still leads in advanced nuclear reactor technology innovation, the technologies will die on the vine without commercial customers, and the Navy will not benefit from these technological advances to update the reactors in its fleet.

As recently as 2013, the U.S. had 104 operating nuclear power plants. Today there are 98 and about 1/3 of them are uneconomic and at risk of premature shutdown. Nuclear power provides immense amounts of carbon free, base load power. However, market pressures brought by abundant natural gas and subsidized wind and solar power, are increasingly driving out nuclear energy in our country. Several expert views suggest that all U.S. commercial nuclear plants are at risk of shutdown within the next 20 years.

With the demise of civil nuclear power, we will see decline in much of the infrastructure that is also critical to Naval Nuclear Propulsion. The decline of university programs, supply chain, a highly skilled and experienced workforce, and strategic thought leadership in nuclear energy are pushing the U.S. into total irrelevancy at a time when Russia and China are dominating the global market place. And the U.S. ability to influence non-proliferation standards and global safety standards is becoming mute.

In my view, U.S. government leadership, particularly by the Congress and by the Executive branch, is necessary to act to preserve our national security interests.

Thank you for the opportunity to appear before you.

Admiral William J. Fallon
United States Navy (Retired)

Admiral William J. Fallon retired from the U.S. Navy after a distinguished 40 year career of military and strategic leadership. He has led U.S. and Allied forces in eight separate commands and played a leadership role in military and diplomatic matters at the highest levels of the U.S. government.

As head of U.S. Central Command, Admiral Fallon directed all U.S. military operations in the Middle East, Central Asia and Horn of Africa, focusing on combat efforts in Iraq and Afghanistan. He led the U.S. Pacific Command for two years, directing political-military activities in the Asia-Pacific region. His achievements include a resumption of military engagement with China, new outreach to India, a new agreement on a strategic framework with Japan, and humanitarian assistance to the victims of the 2004 Tsunami in SE Asia. He also served as Presidential Envoy to Japan, handling bi-lateral relations after the collision of a U.S. submarine and a Japanese fishing vessel.

On September 11, 2001, Admiral Fallon was serving in the Pentagon as Vice Chief of the Navy. He personally directed the recovery of the Navy staff in the wake of the attack and led in the planning of the retaliatory attacks on Al Qaeda and Taliban forces in Afghanistan. He later commanded the U.S. Atlantic Fleet and U.S. Fleet Forces Command, with responsibility for the readiness of U.S. Naval forces worldwide.

Admiral Fallon began his Navy career as a combat aviator flying from an aircraft carrier during the Vietnam War and participated in many vital U.S. military operations during the Cold War. He led a Carrier Air Wing in combat during the Gulf War of 1991, and commanded a Navy Battle Group and the U.S. 6th Fleet Battle Force during NATO military operations in Bosnia.

Admiral Fallon was a Robert E. Wilhelm Fellow at the Massachusetts Institute of Technology, Center for International Studies. He serves on the Global Affairs Advisory Board of Occidental College and the International Advisory Board of the University of California, San Diego, School of Global Policy and Strategy. He is a graduate of Villanova University, the U.S. Naval War College, the National War College, and has an MA in International Studies from Old Dominion University.

Chairman of the Board of CounterTack Inc., a company in the cyber security business, Admiral Fallon serves on the board of FastData.io, is a partner in Tilwell Petroleum, LLC, and Global Alliance Advisors, LLC, a Washington based consulting group. advisor to several other businesses and a Senior Fellow at the Center for Naval Analyses. He has been a member of an Experts Panel to the Congressional Commission on the Strategic Posture of the U.S. and served as Co-Chair of the Center for Strategic and International Studies Commission on Smart Global Health Policy and Co-Chair of the National Association of Corporate Directors 2009 Blue Ribbon Commission on Risk Management. He is a member of the U.S. Secretary of Defense Science Board and the Board of the American Security Project.

Chairman LAMB. Thank you very much.
Ms. Taylor.

**TESTIMONY OF TINA M. TAYLOR,
SENIOR DIRECTOR, RESEARCH AND DEVELOPMENT,
ELECTRIC POWER RESEARCH INSTITUTE**

Ms. TAYLOR. Good morning, Chairman Lamb and Members of the Subcommittee. I appreciate the opportunity to participate in today's hearing.

EPRI (Electric Power Research Institute) conducts research relating to the generation delivery and use of electricity for the benefit of the public. An independent nonprofit organization, we bring together experts to help address challenges in electricity, including reliability, efficiency, affordability, health, safety, and the environment. EPRI sees a plausible future where deep carbon reductions will require continued focus on energy efficiency, cleaner energy, electrification, and advanced fuels. Nuclear power plays an important role to achieve carbon reductions while providing affordable energy and a strong GDP.

As was mentioned, it's fitting that we're here next to the Shippingport station today, the first demonstration of large-scale commercial power—nuclear power in the U.S. After 25 years of operation, Shippingport has been decommissioned successfully and the land released for unrestricted use. Currently operating at the site are the two units at Beaver Valley that you toured this morning. While both of these units have received license extensions from the NRC, FirstEnergy has announced potential premature closure due to market challenges and, today, Beaver Valley's future remains uncertain.

Nuclear plants have long been valued for their reliable operation and contribution to baseload generation, and now they're being reappraised as a foundation for sustained decarbonization, economic contributions, environmental footprint, and other societal benefits. The 98 operating reactors today provide nearly 20 percent of the electricity in the United States, and even with rapid deployment of wind and solar, nuclear plants still comprise about 60 percent of our carbon-free electricity.

While a number of units in the U.S. are currently under financial stress, that picture can change dramatically if the U.S. places even a modest value on carbon reductions. The current nuclear fleet operates safely and has achieved very high reliability. The extended operation could provide an important foundation for the future of nuclear.

Plants were initially licensed for 40 years from the NRC with the potential for extended license periods of 20 years. Currently, 90 of the operating reactors have received license extensions to operate out to 60 years. The focus now is on renewal of these licenses to allow operation out to 80 years. So far, three companies have applied to the NRC for these second license extensions, and other companies are evaluating this option. Based on extensive research, evaluation of inspection results, and development of aging management programs, we have found no technical barriers to safely and reliably extending the life of these plants out to 80 years and potentially beyond.

New technologies and process improvements can also enable extended operations, providing improved economics while maintaining reliability and safety. Two examples of this are accident-tolerant fuel and plant modernization. Acceleration of these technologies can increase efficiencies, and EPRI is engaged with the Department of Energy and others to evaluate these options.

The longer and more efficient operation of today's fleet provides a bridge to the next wave of nuclear technologies. This is important to provide additional time for development and deployment of new plant types and to help maintain the national nuclear expertise, as Admiral discussed, and the supply chain.

SMRs (small modular reactors) are a likely near-term option. EPRI has worked with stakeholders to accelerate adoption of these technologies, leverage the improvements in design, and is demonstrating advanced manufacturing technologies. Increasing industry and government interest in advanced reactors has coincided with an unprecedented influx of private investment. We're working on advanced reactor owner-operator requirements, developing methods for integrating safety assessments during the design phase, and performing economic modeling to explore where these plants may fit in the future.

Opportunities for nuclear power increase substantially if decarbonization of transportation, building, and industrial sectors is seriously pursued via economy-wide electrification or through low-carbon energy carriers such as hydrogen.

In conclusion, research and development (R&D) to optimize and extend the life of existing plants and demonstrations of advanced nuclear technologies offer utilities and other stakeholders several options for reliable, efficient carbon-free energy.

Thank you again, and I look forward to any questions you may have.

[The prepared statement of Ms. Taylor follows:]

Hearing of the Subcommittee on Energy, House Committee on Science, Space and Technology

Tina Taylor

Senior Director Research & Development, Deputy Chief Nuclear Officer,

Nuclear Sector, Electric Power Research Institute

Hearing titled "How the Domestic Nuclear Industry Boosts Local Economies, Curbs Emissions, and Strengthens National Security"

May 3, 2019

Background

The Electric Power Research Institute (EPRI) conducts research and development relating to the generation, delivery, and use of electricity for the benefit of the public. An independent, non-profit organization, EPRI brings its scientists and engineers, as well as experts from academia, government and the industry, to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI's members represent approximately 90 percent of the electricity generated and delivered in the United States, and international participation extends to more than 35 countries.

The subject of my testimony today is EPRI's collaborative research efforts related to long term operation of the existing nuclear fleet and future commercial nuclear plant options including small modular and advanced reactors.

EPRI sees a plausible future where deep carbon reductions will require continued focus on energy efficiency, cleaner energy, electrification and advanced fuels. Nuclear power plays an important part of cleaner energy and advanced technologies needed to achieve carbon emissions reductions, affordable energy for the customer and a strong gross domestic product (GDP).

Location

It is fitting that we have this discussion just down the road from the site of the Shippingport Atomic Power Station. Shippingport was the first demonstration of large-scale commercial nuclear power in the United States, and the first dedicated solely to peaceful use of atomic energy worldwide. It was connected to the grid in 1957 and operated for 25 years prior to being shut down in 1982. The plant has been decommissioned and the land released for unrestricted use.

Over its 25-year lifetime, Shippingport operated with three very different core designs. With these different designs, the plant demonstrated many aspects of fuel, materials, and operation that underpin light water plants currently in operation. It also successfully demonstrated core designs and fuel cycles that are more characteristic of many advanced reactors under development today,

including so-called "seed-and-blanket" core configurations and the ability to breed more fissile fuel than consumed.

Currently operating at the same site is the Beaver Valley Power Station with two pressurized water reactors. The first unit at Beaver Valley was licensed in 1976. With a license extension granted by the Nuclear Regulatory Commission in 2009, the plant is currently licensed to operate until 2036. The second unit came on line in 1987 and is currently licensed to operate until 2047. However, in 2018, Beaver Valley plant owner FirstEnergy announced a potential premature closure in 2021 due to market challenges. Beaver Valley's future is still uncertain.

On one site, what we would now think of as an advanced reactor has been demonstrated, extended operation of the two pressurized water reactors is well underway and a successful decommissioning effort has been completed.

Current status and license extension

Nuclear plants have long been valued for their reliable operation and contribution to baseload power generation. Many stakeholders, including owners and operators, regulators and government agencies, financial institutions and researchers are reappraising them as a foundation for sustained decarbonization – both on their own and in conjunction with renewables. Stakeholders are also assessing nuclear plants' economic contributions, local environmental footprint, and many other societal benefits.

The Beaver Valley plants are just two of 98 reactors currently operating in the U.S. These 98 reactors provide nearly 20 percent of the electricity generated in the US. Even with rapid deployment of wind and solar generation over the past decade, nuclear plants still comprise approximately 60 percent of our carbon-free electricity. While a significant number of units are currently under financial stress, that picture can change dramatically if the U.S. places even a modest value on carbon emissions reductions. And in a low-carbon future, reliable, dispatchable generation provides growing value as variable generation deployment expands.

The current fleet of reactors operates safely and has achieved very high reliability. They form a solid foundation for our nation's energy infrastructure and their extended operation could provide an important bridge to the future where new reactor technologies are commercialized, providing a wider range of applications for nuclear energy.

The current fleet of reactors operate safely and has achieved very high reliability. They form a solid foundation for our nation's energy infrastructure and their extended operation could provide an important bridge to the future where new reactor technologies can be commercialized, providing a wider range of applications for nuclear energy.

The Nuclear Regulatory Commission (NRC) originally licensed plants to operate for 40 years, with the potential for extended license periods of 20 years. Currently 90 of the operating reactors have received approval to extend their license out to 60 years, and more than half of the plants have operated for greater than 40 years. This forms a strong foundation of operating experience for second license renewals.

The NRC and plant owners are now focusing on renewals that would extend licenses out to 80 years. Absent second extensions, U.S. nuclear units will retire as they reach the end of their 60-year lives, and nuclear generation would begin a steep downward slope in the early 2030s. By 2035, approximately 30,000 of today's 100,000 megawatts of nuclear capacity would be offline and by 2050, the current light water reactor fleet would be nearly gone.

License renewal involves a systematic review of the plant, identification of potential degradation mechanisms and the development of aging management programs. It proceeds through coordinated efforts on three distinct fronts – regulatory, technical and environmental reviews.

Over the last 20 years, EPRI has been engaged with utilities, the Department of Energy (DOE) and the NRC to develop appropriate aging management programs. EPRI draws on a broad body of technical expertise and decades of research in materials, engineering and plant operations. The results of our research help provide the technical basis that can inform utilities' license renewal efforts and aging management programs.

For second license renewal, the key components of EPRI's research and guidance included:

- Reactor pressure vessels
- Reactor core internals
- Concrete and civil structures
- Electrical cables

Effective aging management requires an understanding of the aging mechanisms, when and how to inspect, along with thorough evaluation of inspection results and informed repair and replacement decisions.

Based on extensive research, evaluation of inspection results, and development of the aging management programs, we have found no technical barriers to safely and reliably extending the life of nuclear plants out to 80 years. This depends, of course, on nuclear plant owners effectively implementing the aging management programs.

So far, three companies have submitted applications for second license renewal. Experience from the Turkey Point, Surry and Peach Bottom license renewals will inform second license renewal decisions for other U.S. utilities. Success in the U.S. also is helping to inform international license renewal guidelines and safe operations in countries where nuclear plants are often 5 to 10 years younger.

New technologies for existing plants

New technologies and process improvements can also enable extended operations in existing plants, providing improved economics while maintaining reliability and safety. Two examples of initiatives that EPRI is working on are Accident Tolerant Fuels and Plant Modernization.

EPRI has been working with the DOE, fuel vendors, plant operators and other stakeholders to understand the application of different types of reactor fuels that are more robust and have improved performance during normal and accident conditions. The first accident tolerant designs have already been loaded into U.S. reactors on a limited basis and additional designs will be

loaded in the near future.

EPRI's Plant Modernization initiative is investigating the potential to leverage various technological innovations that can increase efficiencies, thus improving the economics of operating a nuclear plant. These innovations include areas such as digital upgrades, on-line monitoring, digital worker tools and automation.

The longer and more efficient operation of today's fleet provides a bridge to the next wave of nuclear generating facilities. This is important to provide additional time for development and deployment of new plant types and to help maintain the national nuclear expertise and supply chain.

New Plants, SMRs and Advanced Reactors
Large light water reactors similar to those in the U.S. fleet continue to be built around the world with 56 plants currently under construction. In our country, while the NRC has issued combined licenses for 14 plants, only two are under construction at the Vogtle plant in Georgia.

Considerable research is underway to bring new technologies to commercial availability. Small modular reactors are a likely near-term option targeting the mid to late 2020s.

The NuScale Power small modular reactor is currently under design certification review by the NRC, and other SMR technology developers are at various stages of design and development. Utah Associated Municipal Power Systems has announced it is investigating the feasibility of building the first-of-a-kind multi-unit NuScale power plant on a site at the Idaho National Laboratory. NuScale estimates that the first plant will be in commercial operation by 2027.

EPRI has worked with the DOE, current nuclear operators and small modular reactor developers to help develop a common understanding of the requirements operators will have for the construction and operation of these plants. This is published as an EPRI report titled "Utility Requirements Document." Additionally, EPRI has conducted research to better understand the behavior of these containment designs and has evaluated how the plants can leverage new technologies to optimize staffing.

EPRI is also conducting research activities to demonstrate advanced manufacturing solutions which could help reduce the cost and streamline the schedule of building small modular reactors while improving performance of these components.

Looking beyond small modular light water reactors, EPRI has been engaged with the growing community of advanced reactor developers. Increasing industry and government interest in these reactors has coincided with unprecedented influx of private investment. A primary driver for renewed interest in advanced reactor technology is the desire for scalable generation options in the 2030–2050 timeframe to address the approaching scheduled retirement of traditional baseload capacity, while meeting future energy demand and planning for uncertainty resulting from policy, regulatory, and market changes.

Many technologies are being explored today, with several of these designs based on experimental work done prior to the build out of the current large, light water reactor fleet. Shippingport is one example of these early demonstration projects.

Some of the technologies being developed for commercialization include: gas-cooled fast reactors, lead-cooled fast reactors, molten salt reactors, sodium-cooled fast reactors, supercritical-water-cooled reactors, and very-high-temperature reactors. Other forms of advanced nuclear technology are being pursued for applications including energy production, but are still in the fundamental research stage. These include fusion, fission-fusion hybrids and accelerator-driven systems.

Supporting research underway at EPRI includes development of advanced reactor owner-operator requirements, developing methods for early integration of safety assessments during design, and economic modeling to explore the future role for nuclear in the U.S.

Opportunities for nuclear power increase substantially if decarbonization of transportation, building and industrial sectors is seriously pursued via economy-wide electrification or through low-carbon energy carriers such as green hydrogen. Both SMRs and advanced reactors offer unique features and attributes, including substantial increases in safety, to support new applications and disruptive business cases through greater operational, deployment, and product flexibility not as readily available from current technology.

Concluding Remarks

The nation's nuclear fleet continues to perform safely and reliably. While some of today's plants are facing economic pressures, several companies are working on extending the life of current plants out to 80 years and beyond. EPRI's research can inform these decisions as well as help provide the technical basis for effective aging management.

Small modular and advanced reactors provide new options beyond traditional large nuclear plants. Many companies are working on developing various designs for advanced reactors. EPRI is working collaboratively with several stakeholders on the development and demonstration of new technologies that may help inform utilities and vendors in achieving their objectives for design, construction and operation.

Research to optimize and extend the life of existing plants and demonstrations of advanced nuclear technologies offer utilities and other stakeholders several options, which is arguably among the most valuable resources they can have at their disposal in the future.

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Tina M. Taylor
Deputy Chief Nuclear Officer
Senior Director, Research & Development
Nuclear Sector

Tina Taylor is Deputy Chief Nuclear Officer and Senior Director, R&D and at the Electric Power Research Institute (EPRI). She is responsible for a diverse portfolio of research addressing the most technically challenging issues facing nuclear power. Her team is responsible for work in the areas of maintenance, engineering, equipment reliability, instrumentation and control, risk and safety management, chemistry, fuel, high and low-level waste, and decommissioning. Additionally, Taylor is leading EPRI's efforts related to training and technology transfer.

Taylor has worked in the electric power industry for more than 30 years and joined EPRI in 1997. At EPRI, she has worked in a breadth of areas including nuclear power, environment, sustainability, renewables and engineering services.

Prior to joining EPRI, Taylor specialized in chemistry and corrosion in nuclear plants, working as a senior engineer at B&W Nuclear Technologies and before that as an engineer at Northeast Utilities.

Taylor holds a Bachelor of Science degree in chemical engineering from Tufts University.

Chairman LAMB. Thank you very much, Ms. Taylor.
And, Dr. Apt.

**TESTIMONY OF DR. JAY APT,
PROFESSOR, CARNEGIE MELLON UNIVERSITY'S
TEPPER SCHOOL OF BUSINESS, AND THE
DEPARTMENT OF ENGINEERING AND PUBLIC POLICY**

Dr. APT. Thanks very much, Chairman Lamb, other Members of the Committee, for giving me the opportunity to testify.

I'm going to talk about something that we haven't talked about directly here, and that is non-carbon pollution. We're still killing prematurely 10,000 people a year from conventional pollutants from the power industry. We used to be killing 40,000 when I was growing up, and that's down, but the levels of pollution that we have from conventional power plants are still responsible for shortening your life expectancy by 6 months. Federal and State policies have made a pretty big difference in making that a lot better. I think that we need to keep doing that at both the Federal and the State levels.

Much of the discourse about low-pollution power has focused on renewables, but renewable and low pollution are not synonyms. As folks have said, nuclear provides about 19 percent of the low-pollution power in this country. Renewables provide about 17 percent.

Renewable energy resources are what I've spent a long period of my research career studying. They are a key part of the Nation's future. If demand for electric power stays where it's been since 2007, all of the renewable sources taken together—wind, solar, hydroelectric, geothermal—would account for about 35 percent of U.S. electric generation by 2030. That's good, but if the nuclear plants close by 2030, then that effect would be that low-pollution generation would be right where we are now. If the nuclear plants stay open, we'd be at about 55 percent low-pollution power. If the nuclear plants close, we'd be back down to 35 percent, right where we are today.

So I'd like to make the following points. As other folks have said, nuclear generation provides a bit over half of the low-pollution power that we have in the country. The remaining half is provided by hydroelectric, wind, solar, and geothermal. Wind and solar are growing, but if the USA's nuclear plants close, say, by 2030, then that effect would be no increase at all in our low-pollution power.

States have a big role to play. The U.S. Supreme Court's decision on April 15 to allow low-pollution programs to go forward in Illinois and New York are a clear indication that States can treat low-pollution power the same way that they treat renewable power.

Let me move to the Federal role. Spent fuel storage for civilian and military reactors is a Federal responsibility. Funds have been collected from each kilowatt hour produced by our Nation's nuclear power generators to pay for a long-term spent fuel solution. The Federal Government must shoulder its responsibility.

The Department of Energy has a bunch of great national labs. They have excellent expertise in the materials science that's relevant to the continued operation of a fleet of nuclear generators. Continuing DOE research into the ways that nuclear fuel elements,

for example, can become more tolerant of transient temperature excursions is one appropriate area for Federal action.

Finally, if we're going to have safe and affordable advanced reactor designs that can be deployed at scale by midcentury, the United States is going to need to dramatically increase and refocus the budget of DOE's Office of Nuclear Energy toward advanced reactor development.

The DOE's nuclear energy efforts have been scattered. They need to be centralized, and that may mean some difficult choices like the ones that we made in the base realignment and closings for our military services to refocus those appropriately. Part of that increased budget would be dedicated to building new infrastructure such as Fast Flux Test Facilities and other system testbeds. Even with a higher budget, surge funding may be needed to get reactor development and programs to commercialization. We're going to have to down-select to two or three real designs and commercialize those.

Thank you for the opportunity to testify on this important matter, and I'd be pleased to answer any questions when the time comes.

[The prepared statement of Dr. Apt follows:]

Testimony of
Dr. Jay Apt

Professor, Tepper School of Business and Department of Engineering & Public Policy
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U.S. House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Energy

Field Hearing on
How the Domestic Nuclear Industry Boosts Local Economies, Curbs Emissions, and Strengthens National Security

May 3, 2019
Shippingport, Pennsylvania

Chairman Lamb, Ranking Member Weber, and members of this subcommittee, thank you for giving me the opportunity to testify.

At Carnegie Mellon University, I am a professor in the Tepper School of Business and in the Engineering College. CMU professor Granger Morgan and I co-direct the Carnegie Mellon Electricity Industry Center. The opinions here are mine and do not necessarily reflect the views of Carnegie Mellon University, or those of any other institution.

I commend you for examining domestic nuclear power's effects on local economies, air emissions, and national security. I've spent over a decade studying our electric power industry, including low-pollution sources of electric power such as wind, solar, hydroelectric, and nuclear.

Federal and state policies have made a large difference in reducing the adverse human health effects of electric power generation, by limiting the emissions of particulate matter, sulfur dioxide, oxides of nitrogen, and mercury; by funding the initial development of techniques to recover natural gas from shale formations; by providing federal tax credits and state quotas for renewable electricity sources; and by investing in the development of nuclear power to generate electricity.

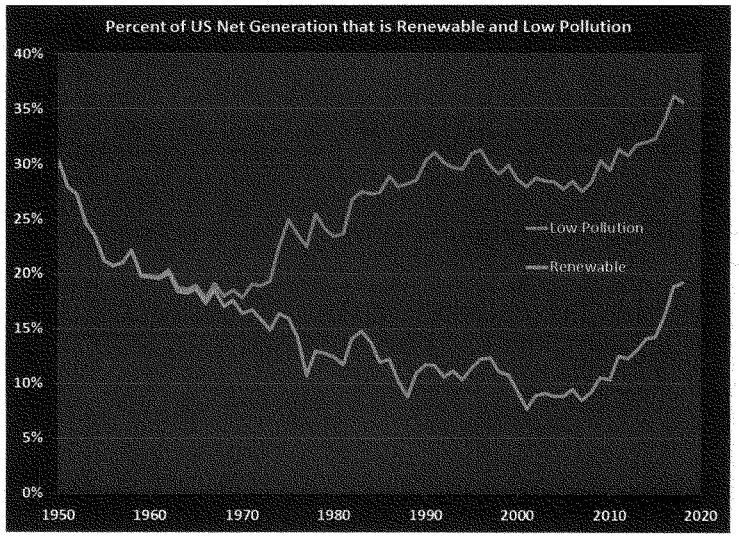
These policies have reduced the number of annual premature deaths due to air pollution from power plants in the USA from well over 40,000 per year when I was growing up to about 10,000 per year now. While particulate matter emissions are still responsible for decreasing Americans' life expectancy by roughly 6 months[1], that reduction in life expectancy is considerably smaller than it used to be.

While much of the public discourse about low-pollution power has focused on renewable generation, "renewable" and "low-pollution" are not synonyms.

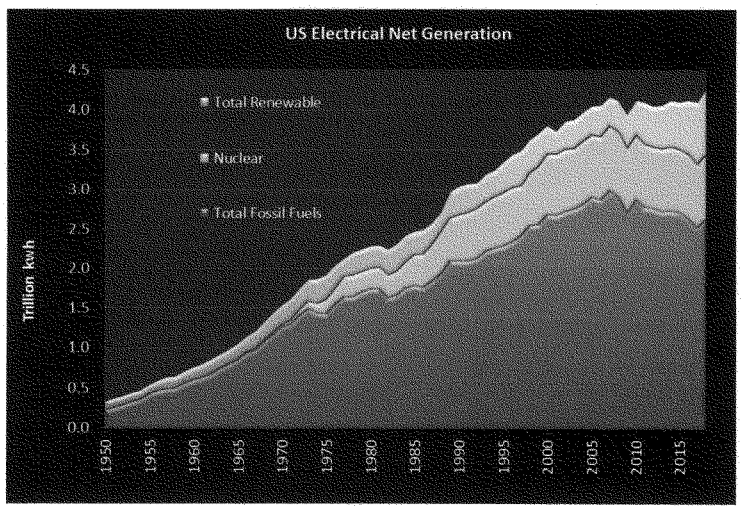
The following graph shows the percentage of the USA's electric power that was generated by renewable sources (water, wind, solar, geothermal) and by low-pollution sources (those plus nuclear power) from 1950 through 2018, according to figures published by the US Energy Information Administration. Renewable energy as a percentage of electricity generation in the United States fell from 30% in 1950 to a low of 8% in 2001, as the market share of hydroelectric power was eroded by fossil fuel generators (largely coal and oil) built to keep up with rapidly increasing demand for electricity. Even though production from the USA's hydroelectric plants tripled from 1950 to 1973, demand for electricity grew nearly six-fold in the same period. It was only in the past decade that wind and later solar added to renewables' market share, bringing the total it up to 17% in 2018.

Nuclear generation today provides half of all low-pollution electric power in the USA.

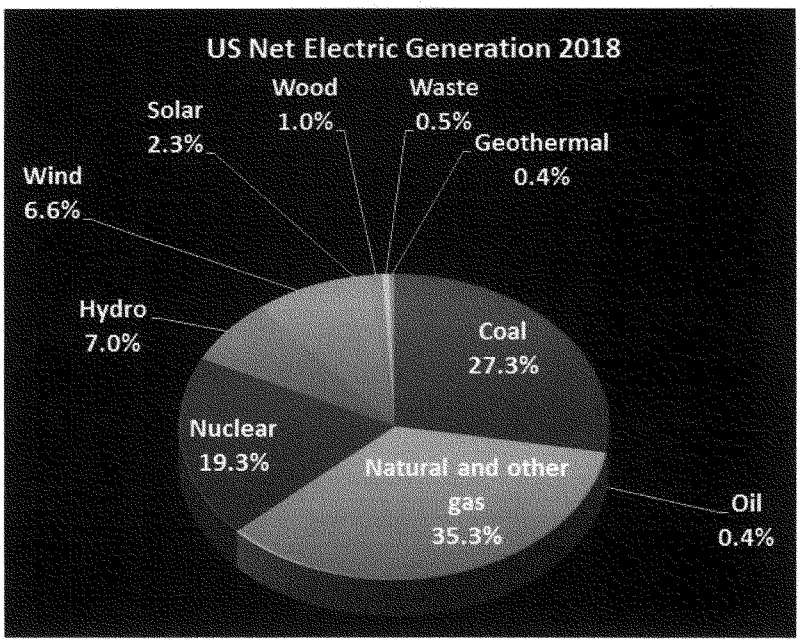
[1] Ambient PM2.5 Reduces Global and Regional Life Expectancy, Joshua S. Apte, Michael Brauer, Aaron J. Cohen, Majid Ezzati, and C. Arden Pope, III, Environmental Science & Technology Letters 2018 5 (9), 546-551, DOI: 10.1021/acs.estlett.8b00360



Coal and oil generation increased by a factor of 5 from 1950 to 1970 to keep up with the demand for electricity. What greatly helped to slow the resulting rapid increase in pollution was the introduction of nuclear power at large scale in the early 1970s.

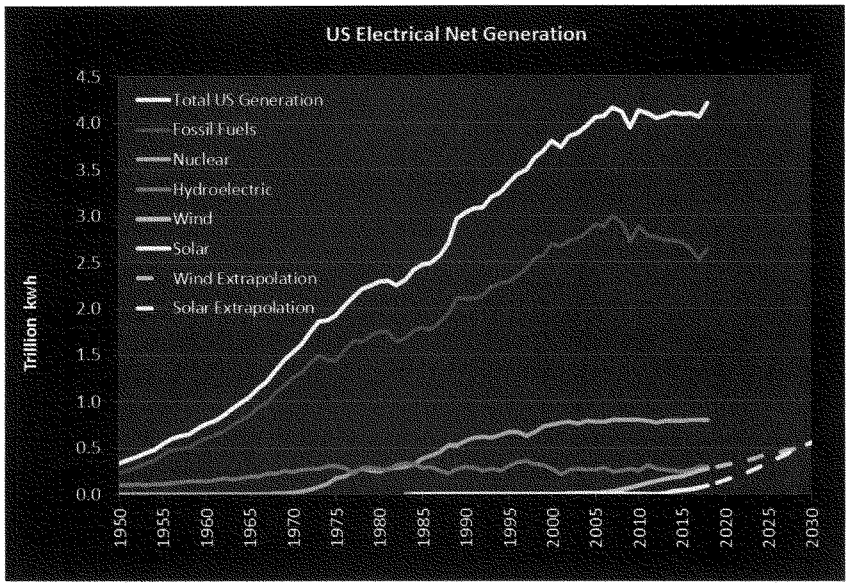


Nuclear power's share of all USA electric power production grew from zero in 1956 to its peak of 21% in 2002. Nuclear power continues to provide 19% of our electricity, while renewables (including hydroelectric) provide 17%.



Renewable energy sources are a key part of the nation's future, but all available low-pollution sources is the best, and most cost effective, way to achieve the goals of reducing air emissions *and* the atmospheric concentration of carbon dioxide.

Wind and solar power have been growing in the past decade. Extrapolating the linear growth of wind and the quadratic growth of solar leads to a significant increase in their generation by 2030, as shown in the figure below.



If demand for electricity stays at the level where it has been since 2007, taken together all renewables—solar, wind, geothermal and hydro—would account for 35% of US electricity generation in 2030 (making the reasonable assumption that hydroelectric power and geothermal won't increase).

That's good, but if the USA's nuclear plants close, by 2030 the net effect would be no increase in low-pollution power. With nuclear, by 2030 we would be at 54% low-pollution electricity. Without nuclear, we would be at only 35%, right where we are today. Clearly, keeping nuclear in the mix is important to a low-pollution future.

Since this hearing is in Pennsylvania, I note that in 2017 39% of Pennsylvania's electricity was produced by nuclear power. The Commonwealth's five nuclear power plants provided 92% of all Pennsylvania's low-pollution power in 2017, the most recent year for which the Energy Information Administration has published state-level data. Because some nuclear plants find they cannot compete against low cost natural gas in today's electricity market, three units, representing 27% of the nuclear generating capacity in the Commonwealth, have announced that they plan to close (the unit at Three Mile Island in 2019 and the two units at Beaver Valley in 2021).

States such as Illinois and New York have recently modified their low-pollution power generation incentive programs to include nuclear plants in the portfolio of low-pollution sources. The US Supreme Court on April 15, 2019 allowed rulings by the 2nd and 7th US Circuit Courts of

Appeals to stand that rejected claims that programs in those two states intrude on the jurisdiction of the Federal Energy Regulatory Commission. Thus, programs such as the Illinois and New York ones appear to be acceptable state prerogatives, and other states currently are deciding what role to play in determining whether low-pollution power incentives should be applied.

At the federal level, there are a number of actions that could be useful if nuclear power is going to continue to supply low-pollution power at scale in the USA.

The responsibility for storage of long-lived spent nuclear fuel from civilian and military reactors is a federal responsibility that has not been adequately discharged. While the nation continues to work on permanent solutions for this problem, the situation at civilian power reactors could be improved considerably by developing long-term storage that would allow spent fuel that is now piling up in storage at individual reactor sites to be moved to much safer centrally managed locations.

The US Department of Energy and its national laboratories have a large role to play in understanding how the materials used in nuclear power plants can be monitored as the plants enter middle age. Continuing DOE research into the ways nuclear fuel elements can become more tolerant of transient temperature excursions is one appropriate area of federal action.

In the medium term, as my colleague Professor Granger Morgan and his coauthors have written[2], "To assure that we have safe and affordable advanced reactor designs that can be deployed at scale by midcentury, the United States will need to dramatically increase and refocus the budget of the DOE's NE [office of nuclear energy] toward advanced reactor development. Perceptive and ruthlessly pragmatic program officers will need to be recruited: ones with a sense of the mission's urgency. The government would have to sustain that higher level of support in the face of constant short-term political pressures and, undoubtedly, organized opposition from advocates of other generating sources. Part of that increased budget would have to be dedicated to building new infrastructure, such as fast-flux test facilities and other system test beds. Even with a higher budget, surge funding may be needed in some years to support demonstration reactor development and program leadership would eventually have to focus on moving two or three systematically chosen designs to the point of commercialization."

In summary:

- Nuclear generation today provides half of all low-pollution electric power in the USA.
- The remaining half is provided by hydroelectric, wind, solar, and geothermal power. Wind and solar are growing. However, if the USA's nuclear plants close, by 2030 the net effect would be no increase in low-pollution power. With nuclear, by 2030 we would be at 54% low-pollution electricity. Without nuclear, we would be at only 35%, right where we are today
- The US Supreme Court's decision three weeks ago to allow low-pollution programs in Illinois and New York to go forward is a clear indication that states can choose to support

[2] US nuclear power: The vanishing low-carbon wedge, M. Granger Morgan, Ahmed Abdulla, Michael J. Ford, Michael Rath, Proceedings of the National Academy of Sciences Jul 2018, 115 (28) 7184-7189; DOI: 10.1073/pnas.1804655115

low-pollution power sources in the same way that they can choose to support renewable power sources.

- Spent fuel storage for civilian and military reactors is a federal responsibility. Funds have been collected from each kilowatt-hour produced by our nation's civilian nuclear power generators to pay for a long-term spent fuel storage solution. The federal government should shoulder its responsibility.
- The DOE national laboratories have excellent expertise in the materials science that is relevant to the continued operation of the fleet of nuclear generators. Continuing DOE research into the ways nuclear fuel elements can become more tolerant of transient temperature excursions is one appropriate area of federal action.
- If we are to have safe and affordable advanced reactor designs that can be deployed at scale by midcentury, the United States will need to dramatically increase and refocus the budget of the DOE's office of nuclear energy toward advanced reactor development. Part of that increased budget would have to be dedicated to building new infrastructure, such as fast-flux test facilities and other system test beds. Even with a higher budget, surge funding may be needed in some years to support demonstration reactor development and program leadership would eventually have to focus on moving two or three systematically chosen designs to the point of commercialization.

Thank you for the opportunity to testify on this important matter.

Jay Apt is a Professor at Carnegie Mellon University's Tepper School of Business and in the CMU Department of Engineering and Public Policy. He received an A.B. in physics from Harvard College in 1971 and a Ph.D. in experimental physics from the Massachusetts Institute of Technology in 1976. He is a Fellow of the American Association for the Advancement of Science. He received the NASA Distinguished Service Medal and the Metcalf Lifetime Achievement Award for significant contributions to engineering.

Professor Apt is the director of the RenewElec (renewable electricity) project at Carnegie Mellon University. He and CMU professor M. Granger Morgan co-direct the Carnegie Mellon Electricity Industry Center, one of the world's largest engineering-business centers focused on the electricity industry. The Carnegie Mellon Electricity Industry Center is supported by grants from the Electric Power Research Institute, the Richard King Mellon Foundation, the National Science Foundation, and a number of government agencies, organizations, and companies.

He is the author of more than one hundred peer reviewed scientific publications, and author of several books and book sections. He has published opinion pieces in the Wall Street Journal, the New York Times and the Washington Post.

Professor Apt's web page is https://www.cmu.edu/epp/people/faculty/jay-apt.html.
The publications of the Carnegie Mellon Electricity Industry Center are available at www.cmu.edu/electricity.

Chairman LAMB. Thank you, Dr. Apt.

OK. So just to explain for a second what we're going to do now, in case this wasn't already clear, this is a real legislative hearing the same way that we would conduct one on Capitol Hill in Washington, D.C. We just happened to bring it out here so that more folks could find out what we were thinking and we could learn from all of you. So when we hold these hearings in Washington, we will take testimony from the witnesses like we just did, and then the Members get the chance to ask questions. And it's all designed to lead to a bill that we might draft or a law that we could try to pass on this subject. We're trying to gather the information from the experts themselves. So that's what we'll start to do now.

I will recognize myself as the Chairman of the for about 5 minutes of questioning, and then we'll go through each Member for 5 minutes, and we might do that a couple times to make sure all the questions get out.

So I will start on the end with Dr. Lyons. Dr. Lyons, we have here today four Members of Congress from this Committee, all of whom happen to be Democrats. That's really mainly driven by just the logistics of traveling here and who was available and that kind of thing. I know from working on the Committee that Democrats and Republicans are both very interested in nuclear power.

And I thought you might be able to weigh in on that, as someone who's served in both President Bush's Administration and President Obama's Administration. And you actually quoted—in case anyone didn't catch who you were talking about, you quoted Department of Energy Secretary Rick Perry, the former Republican Governor of Texas and Presidential candidate, who himself has made very supportive comments about nuclear energy.

So I was wondering if you could just weigh in. In your experience, has this been a bipartisan issue?

Dr. LYONS. Chairman Lamb, I would very much agree with you that this is a bipartisan issue. I think it's well-recognized in both houses and both parties that nuclear energy is a vital resource for the country. So, yes, I strongly agree with you.

Chairman LAMB. Great. Thank you very much.

Now, Admiral Fallon, I'd like to follow up on a few of the important things you discussed. One thing is you talked a lot about aircraft carriers. Just very quickly, can we think of the aircraft carriers—they're almost sort of like floating nuclear power plants in a way, right? I mean, they're—people think of nuclear energy and nuclear power as being very dangerous and risky, but actually, the Navy has been doing this for a really long time, carrying them all over the ocean for long periods of time like you talked about. And there's a whole culture of safety and expertise that's built up. Could you talk about that a little bit?

Adm. FALLON. Sure, I'm happy to. So the Navy's got more than 6 decades of operating experience under often extreme conditions, and it's been able to do it safely and efficiently and effectively. And a lot of that's the legacy of the same Hyman Rickover that was the instigator of this plan here. He had a well-appreciated, fearsome reputation in the Navy when he served as Chief Torturer, but his standards were at the highest level, and he insisted on these standards being enforced. And the legacy of that is what pervades the

U.S. nuclear industry to this day and in my opinion needs to be expanded out in the world rather than having Chernobyl and like situations perpetrated. So I think it's really important.

Another comment about the floating powerplant. So today's aircraft carriers have two reactors on them. The original carrier Enterprise had eight. We learned a lot and moved the technology forward. But these plants operate for very long periods of time. The lifetime—the planned lifetime of our aircraft carriers since inception, the nuclear carriers, is 50 years, so Enterprise served 53 years, and the expectation is that we're going to continue that.

So these are actually very versatile vessels. They're large, and you can use them for many things. And the idea is we expect technology is going to change, the nature of conflict will change, but you have a platform that offers you immense, varied capabilities, and I think it's really terrific.

Submarines, a little more focused, smaller, but they're our primary strategic deterrent lest anyone get an idea that they might do something stupid against this country, they're out there 24 hours a day under the seas, very difficult to find, and they're enabled to do that by nuclear power, which keeps them going. So——

Chairman LAMB. And it's that culture of professionalism and safety in the Navy.

Adm. FALLON. So basically——

Chairman LAMB. Yes.

Adm. FALLON [continuing]. The standards are very high, and there's not a lot of tolerance for error. And if you make a mistake, you're gone, but there's a very, very tightly interwoven series of events and activities and procedures in place to check and double check and make sure these things are done correctly and efficiently and safely.

Chairman LAMB. Thank you. Do we happen to have any Navy veterans in the room with us today? I see a bunch of hands. Thank you for serving in the Navy. It's a shame you couldn't be in the Marine Corps, but the Navy is certainly a good option.

But, no, when you walk through the power plant here, I was struck, both times I've been there, by how many Navy veterans you meet who got their start in the Navy's nuclear program. And then they knew that they could move back home at the end of their service when they were ready—many of them are from here originally—and continue to work in the same field, and that's one of the great benefits of this industry.

So with that, I will turn now to my colleague from Michigan, Representative Haley Stevens, for 5 minutes of questions.

Ms. STEVENS. Thank you. Well, allow me to say what a delight it is to be in Beaver County and Shippingport in particular with my incredible colleague and our Chairman Conor Lamb. We've got to give him some credit for his leadership in bringing this field hearing together and allowing us to have this discussion.

We often talk about the Science Committee as the Committee of the future and how we determine our future and come together to win it. And I represent communities not too different than this, this industrial Midwestern heartland. And the questions before us around our future, around a clean and sustainable economy that is creating jobs at scale for all of us, this is what Beaver County rep-

resents. And you have my commitment and partnership that we'll be damned if we let this plant close. And we will continue to work to share the success story about what the industrial might, what the workforce talent here represents and, frankly, how American leadership can be represented in new economies of scale because of what nuclear energy represents.

My first question is for you, Dr. Lyons. In your testimony you described the Nation's nuclear power plants as a vital resource. And in my home State of Michigan, we generate nearly 90 percent of our emissions-free electricity from nuclear power. These are companies, DTE Energy and consumers. We frankly are leaders in this space, and we're thrilled to be connected to all of you here in Beaver County because of that. This is also well over the national average of 55 percent.

Can we just hone in here a little bit more specifically, though, because if plants like this—which, by the way, I had a blast on the tour and I can't wait to come back. But if plants like this were to close, what would the national energy mix look like? What would this do to our energy economy?

Dr. LYONS. Thank you for the question, Representative Stevens. As I indicated in my testimony, I'm concerned that, as we continue to lose plants, we may, if you will, reach a cliff where we lose all of our nuclear power plants. The implications are tremendous. We would be losing over half of our clean energy in the country. There would be a dramatic reduction in the resilience and reliability of the grid. These are factors that are of immense importance to the American public. So I certainly agree with the thrust of your question. I use the word that they're a vital national resource. I absolutely believe that and appreciate your question.

Ms. STEVENS. And so could you just explain a little bit more, too, about how this would impact our greenhouse gas emissions?

Dr. LYONS. There have been a number of test cases around the country and around the world where nuclear plants have closed. They've always been primarily replaced with fossil energy with their resulting emissions. It's very hard to argue any other way. The emissions will increase dramatically, and the concerns that Dr. Apt raised in his testimony will be intensified with the impact of greater fossil emissions.

Ms. STEVENS. And we talked a little bit about the perception of nuclear energy and kind of going into a rich history of which we celebrate and recognizing some of the present-day frustrations with how the public perceives nuclear energy. I almost want to save this for the second round, but I'll just say that one of my favorite thinkers of all time, Dr. Steven Pinker, in partnership with Dr. Josh Goldstein at the top of April published an opinion editorial piece titled, "How Nuclear Energy Can Save the World," how we can do this from places like here in Beaver County.

So, Dr. Apt, just quickly here for us, are there public health impacts both nationally and locally of domestic nuclear power plants that you could share or shed light on for us.

Dr. APT. Yes, they're all positive. The 20 percent or so of our power that is produced by nuclear plants is pollution-free. That's huge, right? We've got about one-third of our power produced by coal plants that have clear and present human health dangers. If

we shifted from nuclear power to fossil fuel, that number of 10,000 premature deaths would go up by 6,000. That's a lot, and so it's pretty clear to me that—and I teach in a business school, so I believe in looking at the economics of things. It's really less expensive to keep something going that you have than it is to build anything new.

And I'm a big proponent of building new wind, new solar. That's great. And I'd love if we kept building wind—it's going up linearly—and if we keep building solar, it's going up exponentially. By the year 2030, if we do that and keep our nuclear plants, we'll go from one-third of our power pollution-free to little over half pollution-free. That's great. If we lose our nuclear, we're in deep trouble.

Ms. STEVENS. Thank you, Mr. Chairman, and I yield back the remainder of my time.

Chairman LAMB. Thank you very much, and now we'll turn to my colleague Bill Foster from the great State of Illinois, which has had a lot of success in supporting and maintaining its fleet of domestic nuclear reactors. And, Representative Foster, you're recognized for 5 minutes.

Mr. FOSTER. Well, thank you Chairman Lamb, and thank you to our witnesses.

You know, this—I'd also like to mention there were supposed to be two more of our colleagues here, the Chair of the Full Committee Eddie Bernice Johnson and a Representative from California. And when the thunderstorms came through, they just couldn't make their schedules work. But the three of us drove in the middle of the night last night because of the importance of this hearing.

You know, we've gone through this, as you've mentioned, in Illinois where we've been struggling with the survival of our nuclear fleet. And we've resolved that favorably in terms of preserving the nuclear things. And to make that happen we had the Republican Governor and the Democratic legislature come together and recognize the importance of that, you know, to the environment and to the workforce of the State.

And you certainly have a mirror-image situation here in the politics, but the logic is the same. And one of the reasons I know that I came is to show support for what I hope, you know, all of the elected officials of Pennsylvania will come through on this.

I also wanted to echo something that Chairman Lamb said about Shippingport. You know, they're—I'm a Ph.D. physicist. I spent most of my career designing and building giant particle accelerators. And there are a handful of legendary places in the history of physics. One of them is Stagg Field on the campus of the University of Chicago where the first nuclear chain reaction took place in—during World War II. Another one is the Trinity Site in Alamogordo where the first nuclear weapon was tested. And a third place on the list is Shippingport where the power of the atom was shown that to me—able to be turned for good at commercial scale with tremendous benefits for humanity and for the environment. And so you should be proud forever that that is going to be in the science textbooks forever what was accomplished here more than 50 years ago.

And, as I said, we've been struggling in Illinois with preserving our nuclear fleet. And so I guess my question to actually all the Members of the Committee, what do you see is similar and different to the situation that Illinois faced when it decided that it had to take action and successfully took action to extend the life of its nuclear reactor fleet?

Yes, Dr. Lyons?

Dr. LYONS. If I may start, Representative Foster, certainly thank you for your question, and thank you for the leadership that your State has shown in this issue. I mentioned that I was Co-Chairman of the American Nuclear Society's Nuclear in the State's Special Committee. There were members from our committee who testified in Illinois at the time of the considerations for preserving your plants. To my knowledge, the situations are virtually identical. Maybe I'm missing a nuance, but I see the situations between Pennsylvania today and where Illinois was a few years ago as virtually the same. Maybe I'm missing a nuance, but I don't see it.

Mr. FOSTER. OK. And any other comments? Yes.

Ms. TAYLOR. Yes, I'll comment to bring in a point that hasn't really been discussed here, which is what the plants are doing. So at the same time as there's challenges from the market and maybe a changing price that can be obtained for electricity, another side of that equation is what it costs to generate that electricity. And the plants that operate in Illinois and in Pennsylvania have been working with the industry across the U.S. to look for opportunities to reduce the cost of producing electricity. There was an industry-wide effort over the last several years called Delivering the Nuclear Promise aimed at that, and EPRI has been engaged in that from the perspective of where technology can be applied to reduce those costs. So the staff at the plants is committed to finding a way to make it sustainable as well.

Mr. FOSTER. I guess I'd like to—also to touch on the economics. You know, it seems like the big dog in here is competition from low-priced natural gas, and that's really what has made things tough certainly in Illinois and I suspect here as well. And there is a—there are serious questions of whether we appropriately price the societal cost of methane, particularly fugitive methane emissions, that if you actually appropriately looked at what Dr. Apt mentioned, the health consequences of polluting power of various kinds, as well as the ecological damage from fugitive methane emissions, and we put a price not only on carbon but on methane and other pollution sources, that the economics would be pretty much turned on its head and nuclear would look very different in that economic—and, Dr. Apt, do you want to——

Dr. APT. Sure. Economists like to call these things unpriced externalities, their fancy word for it. But it basically means if you're not paying the full costs of something, then it's not priced appropriately. And for coal-fired power plants, for pollutants such as sulfur dioxide, particulate matter, nitrous oxide, which applies to both coal and gas plants, we had a great Republican idea in 1990, the Clean Air Act amendments, of capping those pollutants and letting companies trade among them under that cap. That resulted in a great market price for those pollutants.

If we properly priced the fugitive methane emissions, which of course not only are very potent greenhouse gases, 30 times more potent than CO_2 pound for pound, but also cause local here-and-now ecological damages, then an economist would pat us on the back and say you've done the right thing.

Mr. FOSTER. Well, thank you. And I guess my time is up, so I'll yield back the balance.

Chairman LAMB. Admiral, if you want to address that last point, go right ahead.

Adm. FALLON. If I could just pile on a little bit here, from my view, the challenge here is that the electric companies I don't think properly value nuclear energy. And the reality is I believe the same in Illinois, it's the same in Pennsylvania, in my original home State of New Jersey which just enacted legislation to help the power plants in that State, and that is that people see what's close in front of them, and they see the availability of abundant quantities of gas and it's very inexpensive compared to other sources. That is why it is used so much.

But the big picture here is that the baseload availability of nuclear-generated power, not subject to the time of day—solar—or the variances of the wind, but it's steady and it's available 24 hours a day, it's not polluting, it gives you phenomenal resilience. So in the wintertime in these northern States I think you may remember that when the temperature plunges, electricity demand goes skyrocketing, and the folks are scurrying around looking for sources of energy. And they're not going to get it the way it's available in the nuclear way. You've got to go find a fuel. These nuclear plants have years of fuel onsite. They don't have to truck stuff in or pipe it in. It's there and available.

So I think the real issue in each of the States is leadership. The leaders have to see beyond the near-term things, look at the long-term good and the common good for all the people and take appropriate action. So I think it's the same in every one of our States.

Chairman LAMB. Thank you, Admiral.

Now, I will recognize Representative Sean Casten also from Illinois. And I should mention that Representative Casten, Representative Stevens, and myself are all in our very first full term in Congress, so we are focusing on this issue early and hope to stay with it for a very long time. And, Representative Casten, you're recognized for 5 minutes.

Mr. CASTEN. Thank you, Chairman Lamb. In fairness, as a redshirt freshman, the rest of us are true freshmen.

I really want to thank you for pulling this hearing together. I want to thank all the witnesses. Thank you for your leadership. I—I'm a 20-year energy executive consultant, spent 16 years as the CEO of clean energy companies. And I can say with a high degree of certainty that we face two existential threats as a species. One of them is global warming and the other one is Russian nukes. And this panel could not be more important because it touches on both of those. And if we don't figure out how to deal with those, we're not going to leave the kind of planet for our kids that our parents left for us. So thank you all for showing up and for dedicating not just your day but your careers to those issues.

I want to focus a little bit away from the operation of these plants to how we build more of them because once you—if you recognize that those are the two big threats we face, the question is, first, how do we keep the assets running, and then second, how do we build more? Because the fact that we're hitting all these at the end of the life to some degree reflects the fact that we've been unable to build them to any meaningful degree over the last 4 decades.

And I want to start, because I'm a chemical engineer by training, with the energy-efficiency end of the cycle because I—it's where my brain naturally goes. And, Dr. Lyons, if you could help me out, of the total energy that comes into the fuel in a nuclear power plant, when we take it out afterwards, when we remove the campaign, what percent of the total recoverable energy in that nuclear fuel have we used to make electric power?

Dr. LYONS. It's an extremely small number on the order of 1 or 2 percent that has been converted to electric power. But i want to be sure I am answering your question——

Mr. CASTEN. Yes. Yes.

Dr. LYONS. So you're asking of the potential energy that could be available from the fissionable material coming in relative to the electrical output——

Mr. CASTEN. Yes.

Dr. LYONS [continuing]. It is only in the range of a couple of percent.

Mr. CASTEN. So could you then compare what percent of the energy we're recovering in a plant like the Beaver Valley plant we just toured to the percent of sort of the best-in-class facilities around the world? What's the—how does that 1 to 2 percent change?

Dr. LYONS. For all operating nuclear power plants with the exception of a couple of fast reactors in Russia, the number would be about the same. All the remaining plants are—with a few exceptions—plants doing roughly the number I described. Now, there are improvements coming in the future that would dramatically change that number, but for the current generation of light water plants, that would be the correct statement.

Mr. CASTEN. OK. So for the new technologies coming down the path, what are we talking about, that potential increase?

Dr. LYONS. You could look at it in two different ways. A plant like Beaver Valley is about 30 to 35 percent efficient in converting heat energy to electricity. Some of the advanced plants under consideration will change that 30 to 35 percent up to over 50 percent because they operate at much higher temperatures. In addition, there are other classes of reactors that can essentially reuse the spent fuel. Right now, we use a so-called open cycle, a once-through cycle where fuel is used once and, for right now, it only goes into pools and dry casks at the reactor because we do not have a repository; I pray we get our act together on waste management and have that repository. But there are reactor designs that have demonstrated this in this country, the so-called fast reactors, that can reuse that used fuel. And then you're up to extractions that are approaching 100 percent, certainly above 90.

Mr. CASTEN. OK. So if you could help me put this in context, we use about 4 trillion kilowatt hours a year of electricity in the country, you know, somewhere between, you know, a little less than 1 trillion come from nuclear if I'm doing my math right. If we could recover the energy in those spent fuel, and get down to what is theoretically possible, what percent of U.S. electricity could we generate from nuclear fuel?

Dr. LYONS. Well, in principle, you could go to 100 percent, sir, but I would come back to my argument on diversity. I don't think you want to have 100 percent of any energy source.

Mr. CASTEN. Understood. My point is simply that if I'm following the math right——

Dr. LYONS. Your math is correct.

Mr. CASTEN [continuing]. We have enough energy that is sitting—that is currently, you know, effectively going to waste as we reject this heat into the atmosphere that is zero carbon, that is clean, that is theoretically base-loaded, and if—and I don't want to put words in your mouth, but it sounds to me like if we can figure out how to deploy the capital, we have largely solved one of the major existential challenges that we face as a country.

Dr. LYONS. And there are certainly companies in the United States today—there are estimated to be over 50 companies exploring advanced reactors in this country. A number of them are focused on reactors of the type about which you're asking. One of the most public or well-known is Bill Gates and TerraPower, and that is exactly the focus of TerraPower. And I believe Mr. Gates has used some of your words on the existential threat, which he is trying to address.

Mr. CASTEN. Well, I am out of my time, but I want to follow up on the economics of this on the next one, but I will yield back my negative time.

Chairman LAMB. Thank you. Thank you very much. And we'll start a second round.

I'm going to start at the other end here with Dr. Apt. And actually, Dr. Apt, I wanted to ask you something from your personal experience. As I mentioned, you're a former astronaut. You did, I believe, four Space Shuttle missions, including some missions with allied countries like Japan and Russia. So this isn't so much about nuclear energy specifically but more about the importance of how our government makes a commitment to science and scientific research and scientific leadership in the world.

From your experience coming up through NASA, seeing what it's like to train to that degree to do something incredibly risky and dangerous like go into space and to work with other countries to do it, do you see a parallel in why we have to maintain our nuclear fleet, our nuclear science, and especially the people who make up that fleet in order to have leadership in the world and be able to continue that culture that we've built all those years?

Dr. APT. Chairman Lamb, that's a superb observation. When we went to the moon, you know, 50 years ago, that was a bipartisan commitment that stretched over a decade from the time that we were shocked in October 1957 when the Russians launched Sputnik 1 to when we landed on the moon on July 20, 1969. Those kind of

decade-long commitments are critical to doing science and engineering projects of all sorts.

One of the things that we don't have is a commitment where a vendor can go out and say, OK, I'm going to build a big new press that can make the top of the nuclear reactor vessel. We don't have that in this country anymore because there hasn't been the demand for it.

Chairman LAMB. Right.

Dr. APT. And there hasn't been the demand for it because we don't have consistent decade-long commitments. And so you're exactly right. That kind of stuff would help in lots of things. Infrastructure of all sorts requires the length of commitment that President Eisenhower did for the interstate highway system, that President Kennedy did for the moon project. Those sorts of things are absolutely critical.

Chairman LAMB. And that type of commitment would actually allow us to build a lot more of this equipment and material here in the United States instead of buying it overseas like we have to do a lot of times now.

Dr. APT. Yes. And part of the reason why we had trouble building the two nuclear power plants that are still under construction, Plant Vogtle in the south, is that we didn't know how to build big things here very well. The same design, the Westinghouse AP1000, got built in China with our plans much quicker because they still build large stuff. If we have infrastructure commitments, then companies will naturally start building the big forges. We'll start understanding how to do big projects again. And we won't have the time and cost overruns that we see when we do this once every two generations.

Chairman LAMB. That's exactly right. And, Admiral Fallon, I was hoping you could touch on that, too. You mentioned a little bit about the importance for our influence in the world, these overseas opportunities to build plants in the way that Russia is doing it now. And if I'm correct, Russia not only builds them but they'll also operate them for many of these countries, so it's actually Russian scientists and businesses that are benefiting from all of this. You've spent a lot of your career overseas working with foreign governments, working with foreign business leaders. Can you talk about why it's important for us to be in that game and building those plants?

Adm. FALLON. Sure. It's even more than that, Mr. Chairman. So the Russians and the Chinese construct and they own and they operate these plants. And they're paid for typically with long-term loans at interesting interest rates. But effectively what happens is the providing country dominates these—particularly the places in Africa and Asia that can least afford this, and they've got them very beholden to them. And so the people in these countries want electric power like everybody does, and you know what happens here, turn off the power and what happens? We fall apart. So in these countries they're very eager to get it, but it's come at a tremendous price. And the influence that Russia and China are beginning to have in these places is overwhelming, and we're just becoming irrelevant. And it's very important I believe for U.S. leadership to be able to have something behind the talk, to be able to stand

up and do it. And so Eisenhower's initiative to use atomic power in those days, nuclear power for peaceful purposes to provide a need that everybody in the world wanted I think was terrific, and we just kind of lost that now.

And if I could for a minute, I want to make this—this is very personal for me, but my last job was the Commander of all U.S. forces in the Middle East during the wars in Iraq and Afghanistan. And as an incentive to get us to invest in nuclear research and development, to give us some opportunities to change what is still the primary fuel source in the world today, oil. I would tell you that my estimation is about half of our casualties killed and wounded in Iraq and Afghanistan were directly related to our need to truck fuel and water in to operate our facilities in these countries, a staggering number of casualties. These are our people, our soldiers, marines, sailors, and airmen. This is absolutely unnecessary in my opinion. We can do better.

And this is what I think the primary—a significant motivation ought to be at a national scale in this country to motivate the kind of research and development that can give us alternatives. And I'm convinced that we can do it. We've done it before. We have a lot more knowledge today and computing power we never had before. We need to put it to work, but it's going to take leadership, and hopefully—I thank you for this hearing and for going through the travails of travel to get here to put this on, but it's very, very important to our country.

Chairman LAMB. Thank you. Go ahead, Dr. Lyons.

Dr. LYONS. If I could add one point to what the Admiral just said, when the Russians talk about build, own, and operate, for many countries they are also offering to provide all of the fresh fuel and they will take back all of the used fuel. It is absolutely a complete package. When they offer this to a country like Bangladesh, they're not offering it because Bangladesh has a bunch of nuclear experts with whom they wish to work. They're offering it with the idea that they are controlling the energy supply of Bangladesh for the next century.

Chairman LAMB. Thank you. And with that, I recognize Representative Stevens for another round of questions.

Ms. STEVENS. Great. Well, it's evident that we are built for moments like these, and while I certainly don't like to hear the examples of being—squirrels chasing their own tail in terms of why we're in the place that we are in, if you reverse it on its head and look at it, we are in a position where we can seize hold of why we are here. And so the questions I would like to ask and maybe each of you could kind of chime in is why are we here as it pertains to nuclear energy and the threats to the cuts and the plant closures? How do we maybe in an existential way seek to solve it? Thinking big is great. And then if you could also touch on ways in which your current portfolio of work is helping to solve this or some examples that you might have. That would be great.

Dr. APT. Let me start by picking up on your word portfolio. Anybody who looks at fluctuations in any market, stock markets or anything else, knows that you have to put your bets on a lot of different numbers on the roulette wheel because you don't know what's going to come up. We're that way with gas. You're at ground

zero of the shale gas revolution in this part of the world, and gas is produced here in enough quantities that it's driven the price way down. That's great. But I'm an old guy. Look at those gray hairs. And I remember that 10, 12 years ago the price of gas went up from $3 to $12 in a matter of months. Those things happen with commodities.

And one way to look at the nuclear fleet is a hedge against those kind of price spikes. Now, like in any hedge, there's a risk premium that you have to pay. When Southwest Airlines hedged their fuel costs a decade ago for their jetliners and thereby avoided the price spikes that almost killed other airlines, they had to pay a small risk premium for that. I think that's a robust lesson out of economics that we ought to learn in our power system.

Ms. STEVENS. Diversified industries.

Ms. TAYLOR. So I would say one of the reasons we're here now is that the current options to build a new nuclear plant are very large, long-term, expensive plants. We only really have, you know, one type of option right now. And a decision to invest that kind of money to build a plant is—requires looking ahead—80-year future, what is the value of that going to be in 80 years? So that has made it very difficult. There was the birth of the nuclear renaissance where we were going to build a lot of plants. In fact, I think 14 plants have received licenses or sites have received licenses from the NRC. And then the economy changed and things slowed down, electric growth slowed down. So I see that as a current challenge today to any company right now to invest, you know, essentially their full market capitalization in a large project with an uncertain future is very difficult.

But the good news is that all of the work going on in the SMR space and the advance reactor space is really aimed at countering kind of the economy of scale that led to the attractiveness of these large plants with looking at the benefits of small where you can build things in more incremental stages and capture the value. So I think—so the way we work ourselves through this and out of this is to accelerate the development of the next wave of technologies. There are a ton of opportunities for that. There are some things that are already working very well in how the government is helping to accelerate the efforts of private investors who are developing some of these. And I think the example of the NuScale progress and the potential UAMPS (Utah Associated Municipal Power Systems) plant at the Idaho National Lab is a great example of things that can be done together with industry and government to accelerate the future.

Ms. STEVENS. Well, and one thing I read is that China and Korea are building nuclear power plants at one-sixth of the cost that it takes. And I don't know if that has to do with supply chain or, you know——

Ms. TAYLOR. Yes.

Ms. STEVENS [continuing]. And if that leads to you——

Ms. TAYLOR. I would—before I turn it over, I would just say I think part of that is what was already mentioned, that they're in the habit of very—building very large projects, so they've got the skills, capability, and workforce to do that.

Adm. FALLON. To answer that specific question, the reason that they claim to build these at a fraction of the cost is because they're state-subsidized, so the national investment by the Chinese government, the Russian government, they're huge. And so that makes it extremely difficult for our companies right now to compete on a—it's not a level playing field, not even close, so that's probably the biggest reason why you see this tremendous growth from these two entities.

Dr. LYONS. Maybe just to follow a little bit on what Ms. Taylor said, I strongly concur that the small modular reactors, the SMRs, are very likely to be the most attractive option for construction in the near term in this country. The very large plants, the gigawatt-plus plants like are being built in the Vogtle plant in Georgia today, there are few places in the country today, given our well-developed grid, where you need that much power all at once. But there are places where the small modular reactors will make a lot more sense, and you mentioned already the construction that is planned in Idaho.

But if you look abroad, the situation may be very, very different. There are many, many places around the world where gigawatt-plus plants make a lot of sense and probably a lot of them, so we need to be looking at opportunities abroad for designs like our AP1000, like our ESBWR (Economic Simplified Boiling Water Reactor) from GE to move ahead in the markets for gigawatt plants. And then there's any number of countries where their grids are just starting where they couldn't possibly take a gigawatt plant. Their whole grid isn't a gigawatt. But they could take a small modular reactor.

And so I see globally a tremendous market and opportunity for the United States in both large and small. In the United States I think most of our options in the future will be the SMRs that Ms. Taylor suggested.

Ms. STEVENS. Well, it's an American leadership moment, and I just—I continue to hold onto something that the Admiral said, which is that, you know, as it compares to the global indicators, we almost feel inferior.

But as I sit up here with your Congressman, by the way, Mr. Conor Lamb, you have a leader in him. And again, I would just like to recognize his efforts. I don't forget the minute he came up to me on the—or the moment he came out to me on the House floor and passed me an invitation to come here today. And it's particularly special because Beaver County is on my way home. Normally, I fly, but it's the midway point, so I'm just 4 hours west of you all here, about 280 miles, and I think we'll be able to continue this dialog and continue to seize the opportunity and moment before us.

I yield back my time, Mr. Chairman.

Chairman LAMB. All right, thank you. Representative Foster.

Mr. FOSTER. Yes, I guess I would like to just spend a moment talking about the nuclear Navy because it's sort of unique. You know, our—the deterrent, the nuclear deterrent of our country relies on three legs, the intercontinental ballistic missiles, the strategic air bombing, and also our nuclear submarines that go off in the deep ocean and hide where they cannot be detected and they—because they cannot be detected, they cannot be destroyed.

When the President is faced with a decision whether to launch weapons, the horrible situation that he or she could be put in is having to decide whether to push our button in response to an enemy attack that—of uncertain nature.

And so in the case of our land-based systems and the strategic bombing, you know, we face the possibility that our forces could be wiped out because the enemy knows where they are and how to get them. That is not the case of nuclear submarines, and it's unique. It means that we can hold back and we can decide when to counterpunch at a time of our choosing and not be panicked into a nuclear war that will destroy the world. So they're what's referred to as stabilizing.

And the nuclear submarine force is something—if you had to choose between these three legs, there's no question the one you would keep would be the nuclear submarines. And so it's for that reason that I've been proud to have visited the facility in West Virginia where the nuclear fuel is made and the places down in naval yards very near the Capitol where a lot of the very highly classified and brilliant design work is done on those.

And so if we lose the commercial nuclear business in this country, we will—it will make our submarines much more expensive, but we will still have to build them. And so it's a false economy to think that, oh, we can just, you know, let the Koreans, that the Japanese, you know, let the Chinese and Russians do the commercial start stuff and we'll just continue building our subs. Because of the shared workforce that's represented by many of you in this room, it's a—I think it's essential that we preserve for national security reasons alone a strong commercial nuclear capability.

And if you have anything to add to that, I'd be——

Adm. FALLON. Thank you. You've said it all, that the submarines are the most survivable aspect of our nuclear deterrent. And again, the idea is that they—because they're going to be very, very difficult to find and attack, that this survivability is our deterrent against somebody that might think that they could neutralize us, take out our strategic capability, and thereby blackmail us into whatever they want to do. So it's really important.

I believe that the options in the supply chain are not only shrinking dramatically but in some cases I've been told we're down to one supplier in this country to provide absolutely critical components for the Navy nuclear power program, and the reason is because there's just not an opportunity to diversify and, you know, do things economically. So I couldn't agree more. Thank you, Congressman.

Mr. FOSTER. Well, thank you. And also one of the things that I know all of us are going to be very active on in the Science Committee is looking at advanced nuclear designs because of, you know, the real promise that is there, that's recognized both commercially and in the Department of Energy.

For example, just the spent fuel that's sitting there in storage in the pond in the dry cask storage there is enough to operate this plant in principle for more than 100 years just with the fuel that is sitting there in the ground today. And that opportunity is one that we have to understand how we're going to take advantage of it where it is frankly a disgrace of Congress that we haven't dealt

with the nuclear waste problem. You know, we have this thing called Yucca Mountain and a promise that was given that we would accept nuclear waste in the facility, and for various political reasons, that—you know, we have not followed through on that. One of the ways out of that politically is with these advanced designs, the designs that can burn the nuclear energy that's still stored in this spent fuel.

And I was wondering if any of you have—do you have a favorite design, Ms. Taylor, or just an idea for a way forward and making sure that we actually follow through on that promise?

Ms. TAYLOR. Well, I don't have a favorite design, but I'm absolutely impressed by the group of young people that are working on all sorts of designs, several of which are—have this concept of somehow burning the current used fuel. And working through the technology part of that is a challenge, but the uncertainty about how one would go about doing that, if that would ever be legal, if the framework would be in place to use that fuel is a large uncertainty to anybody looking to invest in those technologies today. So I think that's an important aspect.

Mr. FOSTER. From a technological point of view, when one of those is demonstrated, is there any reason that it could not be sited at an existing location such as here?

Ms. TAYLOR. I don't think there's any technical reason why it couldn't be.

Mr. FOSTER. Yes, Dr. Lyons?

Dr. LYONS. May I just add, sir, there are certainly no technical obstacles to the vision that you described. In my mind, the decision that I hope this country will eventually make will be between an open cycle where we are now and a closed cycle, as you just described, where we would reprocess and reuse the fuel. My guess is that this choice will be done on an economic basis but I don't know how to answer the economic question for either an open or closed cycle. We have yet to show that we could open a repository in this country, so I don't have the foggiest idea what that costs.

We also have not done a complete demonstration in order to understand the costs of a closed cycle. The country is committed by law now to use the open cycle and show we can open a repository. I hope we can. I'm not sure it will be Yucca but maybe. But in any case, we're on this path of an open cycle. I would like very much to see us also explore the path of work to understand the economics be of a closed cycle so that the country can make an intelligent decision sometime in the future between the open or closed cycle. There are many potential advantages to going with a closed cycle, but the economics are uncertain in both cases.

Mr. FOSTER. Yes. And I agree, but I think it's important that economic calculation consider both the national security aspects and the necessity of keeping a strong nuclear enterprise going in this country, as well as the secondary environmental damage when you start providing that energy with fossil fuels.

Dr. APT. If I may, let me just say that it's a privilege to be on a panel with the former NRC Commissioner and one of our graduates, Bill Magwood was also on the NRC.

Dr. LYONS. Yes, a very good friend.

Dr. APT. But I have to say Nuclear Regulatory Commission is stretched so thin that their ability to do the kind of oversight of these clean-sheet-of-paper designs is in question. And that's one of the reasons why TerraPower that we talked about before is looking at licensing abroad. I don't want to see that. What I do want to see is additional resources in the NRC to be able to license and test those designs in the United States of America.

Chairman LAMB. Thank you. I will now recognize Representative Casten.

Mr. CASTEN. Thank you, Chairman.

As promised, I want to follow up on the—some of the economic barriers to capital deployment in this space, but I want to start by singing the praises of economics because the—I think a very compelling case can be made that the single-most important thing we did for CO_2 emissions in my professional lifetime was the *1992 Energy Policy Act*. The—actually creating an incentive where people preferentially operated their lowest-cost sources has been a boon to the nuclear industry. You know, the fleet has gone from 60 percent to 90 percent capacity factor. I think the FirstEnergy folks told me this morning that you're only 93 percent capacity factor at the upper end of that tier. And, you know, you're doing that because you've got good people, you're doing that because you're motivated by the right things, and you're also doing it because you're greedy because if you can make money by operating more hours, you operate more hours, and that's a good thing.

Now, having said that, the pernicious side effect of that is that over the course of deregulation, there's a saying that's crept into the energy world that everybody wants to be the third owner of a power plant but nobody wants to be the first owner.

And my question for you, Dr. Apt, is, you know, at a broad level what have we done wrong, but more specifically, is there a market tool that we can use to actually encourage the deployment of new capital in the energy sector or do we have to go back and look at—you know, we knew how to build stuff in the old regulated model. We didn't know how to make the right dispatch decisions all the time, but capacity markets, are they working, can we tweak them to work? What are your thoughts about how we might learn from the last 20 years of history to better deploy capital in this space?

Dr. APT. So the technology changes that have happened in the electric power industry have been largely stimulated by two things. One has been command-and-control regulation for conventional pollutants. If you look at the level of patents for things like sulfur dioxide and particulate matter control, you know, people have done many patents until the *1970 Clean Air Act* and especially the *1990 Clean Air Act* amendments came in, and then the patents went way up. So one of the things that we do right is to have Federal and State regulations that stimulate people to go in their lab and figure out a new piece of technology.

The second, as you mentioned, is competition. That's why we brought in natural gas generators. Our companies have built all coal all the time until restructuring happened and then people said, oh, well, we can build a natural gas plan for one-fifth of the cost in 2 years instead of 8 years.

And the other thing is to have stimulation of low-pollution sources explicitly, renewable portfolio standards, for example, and the kind of low-pollution standards that we have in Illinois and New York and perhaps here in Pennsylvania.

Economists can't argue about the nitpicky details of whether a price on carbon or an all-comers for all-low-pollution standards are best or whether you should have tiers as in Pennsylvania for the advanced energy portfolio standard where one tier is renewables and another tier might be nuclear. The difference between doing any of those and doing nothing at all is immense.

Mr. CASTEN. So let me ask you because you're very humble about your background, but I'm—you know, I know you know that I know that you've been really one of the leading thinkers on figuring out how to get rid of some of these inefficiencies in the system. And so if we presume for a moment that the four of us on this side of the dais have the authority to deputize you as king of the energy system for a day or two, if we get to pick three things that if you make those changes we will cause a greater deployment of capital and clean energy technology using market tools, what are your—where do you see the low-hanging fruit? What's your top three?

Dr. APT. Clearly, you have to first re-examine your question of whether they should all be market tools. The issue with market tools is they lead you to short-term answers. And so you have the dash to gas as it was called. Everybody built gas plants around the time when gas first began available in the energy information age and see if the same prices would stay low, and that's what drove around the year 1999 and 2000, 2001 60 gigawatts per year of gas was built, had the absolutely predictable effect of driving natural gas prices up by a factor of four. So markets are inherently short-term.

One of the things that we can do is to say, well, where are market tools appropriate and where should you have things like a low-pollution standard or, if you'd like, a renewable portfolio standard? Again, we're not running out of fossil fuels, so renewability in itself is not our goal. We're running out of atmosphere in which to put the combustion products of fossil fuels. So low-pollution should be the goal.

And you can have regulations of various types that put in low-pollution. The absolute market solution would be a price on pollutants, including greenhouse gases. That's not likely to happen, and it's cumbersome when it does happen.

Waxman-Markey I testified about some years ago, a decade ago in front of a number of committees, and it got pretty complex, more complex than I expected it to get. I think that a kind of portfolio of command-and-control regulation for pollutants, opening up a window for low-pollution sources, including renewables and nuclear, and then keeping an idea that we ought to have a portfolio are the three things that I would do.

Mr. CASTEN. Thank you, and I yield back.

Chairman LAMB. OK. And we'll do one final round just kind of for parting shots, make sure everyone gets a chance to finish off here. I don't think I'm going to take the full 5 minutes, but I just wanted to flesh out the jobs issue a little bit more because it's been referred to by several of our witnesses.

We've had the chance to talk about the folks that work here at Beaver Valley that work for FirstEnergy that are represented by their locals here today, many of them veterans, extremely important for us to protect those jobs. There is also a wider jobs issue for us here Pennsylvania, and I have with me here a report by the Energy Futures Initiative that looks at the companies in the nuclear supply chain and where they're located and how many of them there are. It's been referred to a few times.

And some of these companies sell equipment both to nuclear power stations like Beaver Valley and to the U.S. Navy, and that it's very important for the future of the Navy's nuclear program that these companies survive because they need to buy their stuff from them. But if they're not able to also sell to Beaver Valley because Beaver Valley closes down, then some of those companies might close down, and then all of a sudden the Navy is stuck when it comes to buying what they need.

And it turns out that Pennsylvania is actually one of the leaders in this area, so if you look at the States that have the highest number of nuclear supply chain companies, we're actually No. 1. We have 71 nuclear supply chain companies here in the State of Pennsylvania. They offer about 655 different types of products, really important things when it comes to valves, boilers, storage containers, pumps, concrete. I mean, they're really the things that make up the power station that we know.

And we are again a huge leader when it comes to having companies that do business both with Beaver Valley and with the U.S. Navy. There are really big companies like Bechtel and Westinghouse and General Electric are some of the examples that you'd probably be familiar with. But that actually goes all the way down the line to smaller companies, too.

And so I wanted to highlight that because that's one of the things that's at stake. If we're trying to support our national security and make sure that the Navy can be a leader in nuclear going forward, they need these companies to survive just like our communities need the companies to survive, too, because people work there.

Admiral Fallon, I think you're responsible—or you're pretty familiar with this issue from your time in the Navy but also some of the work you've done on the outside. You know about the Energy Futures Initiative and this report. Is that a fair description that I've just given of the issue as it faces the Navy?

Adm. FALLON. Sure. There are dozens and dozens if not hundreds of companies all over this great Nation of ours that provide bit-and-piece support for the big names, so Westinghouse, Bechtel, whatever the—there are untold bits and pieces that are essential for the equipment to operate correctly. And those are often overlooked. You know, you just—people don't pay attention to them except at the local level where people are actually employed, and so it's very important.

And the Navy tries to encourage companies to diversify, to spread it out for reasons of redundancy and common sense and also to appeal pretty blatantly to the Congress to support things because it has a direct impact on people in their districts. So I don't know all the details of it, but I can tell you that the general prac-

tice is to encourage companies to have a number of suppliers to give you an option economically and also to encourage the kind of support that we need at the top.

Chairman LAMB. Great. Thank you. And I'll turn now to Representative Stevens.

Ms. STEVENS. Great. I referenced the article from Pinker, Steven Pinker, who's a thinker, right, and I didn't mean for that to rhyme, but he's a psychologist. And in his article I just want to make reference to this. He said—in talking about nuclear energy, he said, "Despite its demonstrable safety, nuclear power presses several psychological buttons." And then he goes on to list what those buttons are, the risks that people associate some of the shock around what, you know, comes with—maybe thoughts around radiation of which Dr. Apt said we don't have any health—negative health effects. In fact, we only have health benefits. We have steam, you know, billowing from the tower, which is great, and he also mentioned that people feel better about eliminating a single tiny risk entirely than minimizing a risk from all hazards combined.

And since we have a panel of experts and we have jobs that we want to keep because they're full of technical talent and industrial might, and Beaver County has got a lot in common with Oakland County, Michigan, western Wayne County, Michigan, where I represent. I'm wondering if you—from your knowledge standpoint if you could just maybe make any mention of awareness that you have with these local efforts around nuclear technology adoption and also, as we talked about some of the new plants and the opportunities for what we can create, who's raising their hand first? I mean, who's—Michigan, obviously, we've adopted some of this. We've put into—we've preserved a couple of our plants. We've had this discussion around what this means for our regional economy. But we want to create more plants. We don't want to just save the one that's here. We want to create more. So who's putting—what's happening at the local level?

Congress has got a role to play here, OK? We legislate. We should do, by the way, all of our hearings in the field. I love this, get us out of the swamp. Let's keep coming in here.

But yet really—and I know we've got some local leaders in the room. If you really want to get something done, you've got to start from the bottom up, your mayors, your township supervisors, your State officials. Who's putting their hand up from what you've seen? And then any other, you know, points on how we can kind of push back against these psychological issues. Dr. Lyons?

Dr. LYONS. Let me just take a crack at a few responses, and I'm sure my colleagues can add a lot more. A number that sticks in my mind is that the average safety of workers at a nuclear power plant is roughly comparable to the safety of workers in an office environment, which is at least an interesting fact that many people may not know.

I think one of the important ways of publicizing the safety of nuclear power plants is to remember that all the workers at those plants live in that vicinity, and the resident inspectors from the NRC are right there in those plants living with their families in that community.

The last point I would like to make, is that where there are surveys of the acceptability of nuclear power in different localities around the country, the numbers are very high in places where people understand nuclear power. I would assume that here in Shippingport, it's like other similar communities. People here understand nuclear power, they understand the incredibly low risks, and they understand the very high safety standards of these plants. In most communities like this one, the support for concentration or expansion of nuclear power is in the 80 percent range.

Ms. STEVENS. Yes. Great. Continue to do it from the bottom up. Did you want to jump in here?

Adm. FALLON. Yes. I'll give you—share an anecdote. So a number of years ago I was appearing before different panel in Washington on the other side of the green felt table, and I was becoming irritated. I was younger, had some arrogance those days, and I was really grinding my teeth because the—some of the witnesses who were spouting absolute complete falsehoods and it was just—kept coming on and coming on and I was just—and so finally, the Chairman said, all right, Admiral, what do you have to say about that?

So I was very impertinent and I said, Mr. Chairman, in my business we deal in facts, and I haven't heard many today. Big mistake. So the Chairman leapt across the table and put his finger close to my chest and said let me tell you something, Admiral. Up here, we deal in perceptions, and the perception is you guys screwed up. So I tried to learn from that, and I think this is a really good example that you brought up.

Ms. STEVENS. Well, I'm going to make—go ahead.

Adm. FALLON. No, so we have these perceptions out there, so it's kind of like back to the 1940s and early 1950s, atomic, uh-oh, you know, that thing, you know, you're going to glow. I remember joking in the first days of Navy nuclear power we'd say, oh, the guys on the ship, hey, you're starting to glow. You know, it's a joke.

But people have these ideas, and they're perceptions. So how do you take on the perceptions? And my experience is that you take them on by being smart, learning, having the facts, but then you have to communicate and explain to people the reality of the way things are.

And I think your comments, Dr. Lyons, are right on. People that live and work around these plants for decades—I've lived on nuclear-powered ships, slept 50 feet off the reactors for months and years on end and many, many days. I'm still here. I'm not glowing too badly, am I?

But I think we need to really make an effort to do that, and it's something that people are beginning to get concerned now. I see Governors and other people in States are recognizing they're being backed up against a wall because these things may go away. Now what are we going to do, folks? So they're kind of getting it, and I think hopefully they'll start to work down at the local level.

But I believe that the very useful role for you—and I commend, again, your willingness to hold this hearing and come all the way out here to do this—is to try to put in place policies at the national level that will enable things to happen. And so incentivizing the R&D—I mean, this country is phenomenal, look at the things—look

at a decade ago, the handwringing over the space program. Oh, my God, we're going down the tubes. We've ceded everything, we're—you know, we're nowhere. Well, guess what? Industry all of a sudden came out of nowhere and they have—there's a series of rockets and airplanes and things if you follow news, so who knows what the future is, but it's certainly turned around a lot.

We can do the same thing here if the right incentives are put in place with the right policies. And there are a whole host of things—and my colleagues here know this a lot better than I do—that are in place that are de-incentivizing people to take the reasonable risks that are necessary I think to give us a future. Thank you.

Ms. TAYLOR. Yes. I'll add a couple thoughts. I agree with you that it's extremely difficult for anyone to understand risk and compare risks of things. I myself am, I know, irrationally afraid of snakes, though there's no data to support that.

But I have seen over the course of my career a big shift from strong opposition to nuclear power to now strong support that's growing, you know, it's becoming more widespread. I think two things are going on that are accelerating that and may be useful to further leverage. One is the change in the view from the environmental community from nuclear waste being a dangerous thing and concern about used fuel to recognizing the environmental friendliness of nuclear and the potential large role nuclear can play in decarbonization.

And the other thing that I've seen is a real fueling of interest from young people, people who are in school right now. I think there was a big success when the DOE decided to invest a lot of its research in universities, I don't know, maybe 15 years ago. Pete, you may have been responsible for that actually. We're now seeing these people who are out of college 5 years, 10 years leading this charge in the advanced reactor space, leading the companies actually and challenging the rest of us who have been in the industry for a long time on the pace at which we can achieve change and ready new technologies for the industry. So I think there are challenges around communications, but I think there's a lot of hope and opportunity in the future.

Chairman LAMB. Absolutely, thank you. And we have touched a little bit today and I'm sure we will as we wrap up on some of the proactive things that the Federal Government can do. But apart from, you know, specific things like loan guarantees and working on how the licensing works and production tax credits and doubling down on research, the biggest thing we need to do is send this signal like you're referencing to the universities, to young people, to the market that this industry is here to stay and that there will be nuclear plants today and nuclear plants tomorrow so that when people want to go into business to make the supplies or they want to choose it as their major in college, they'll do that and there will be the pipeline there to make it all thrive and survive.

Representative Foster, any parting shots?

Mr. FOSTER. Thank you, and thank you, Chairman.

I guess maybe I'd like to just talk to the audience for a moment. You know, it is not an accident that Chairman Conor Lamb was chosen, despite being only a redshirt freshman, to be the Chair of the Energy Subcommittee on the Science Committee. You know, it

is—I've been—I was a scientist most of my life, have been in politics for about 10 years, and in that time you sort of—you learn to spot who the leaders of the future are going to be. And when you see someone who is as smart, is a good guy and a leader like you see in him, you—every one of you who gets a chance to vote for him should be very, very proud that you have a Representative like that.

The other thing that we're doing out here—and, this afternoon, we're all going to be going to the—to NETL, the National Energy Technology Laboratory, one of the national labs. The other hat that I have on here, I'm one of the Co-Chairs of the National Laboratory Caucus, which is a bipartisan group, to make sure that Congress fully appreciates all of the jewels in the research and development crown of this country, you know, that locations like Shippingport are historic because of the commercial and technical significance and also the national laboratories. NETL, which is—as you've all—probably all know, not far from here, is absolutely crucial to—not only to the jobs that it produces but to the technological future of this country. And so I'm very proud to be a part of that as well.

Just I guess I had one last question having to do with electrical supply and cars and electrical cars because, you know, one of the things that make it difficult to support a very large nuclear fleet in this vicinity is that a lot of the load was for steel industries that has gone away. But this is also, you know, probably the center of the universe for self-driving cars and new technology. I know in my district we have Argonne National Lab, which is in the process of developing batteries that will have 5 times the range and will make electric cars, you know, really preferable to fossil-fuel-powered cars. But what will that do to the need for electrical grid capacity? Dr. Apt?

Dr. APT. So I drove here in a Chevy Volt, and, you know, we've spent a long time looking at that. Electric demand in this country went up at almost 8 percent a year from 1950 to 1973. Then it transitioned to linear growth. There's a big difference between exponential and linear. And then in 2007 it went flat, where it stayed. And so folks are looking at what the future may bring.

If we have more electric vehicles, which will help the environment, it should go up. And when it goes up, if it does transition again to growth, then keeping our existing nuclear fleet is going to be terribly important because if that goes away and we fill in with fossil fuel, we are in deep trouble.

Mr. FOSTER. Thank you. And thank you, Chairman Lamb, again, for holding this hearing.

Chairman LAMB. Thank you. Representative Casten.

Mr. CASTEN. I'm going to be pretty brief. Thank you again, Chairman, for pulling this together and everybody for coming. We—all of us on this side of the panel serve on multiple committees, but we're here in our capacity on the Science Committee where our jurisdiction is essentially deciding what the United States should spend its research dollars and how much of those dollars should be, and then holding people accountable in our oversight role.

There's been a consistent theme on this panel about the potential for advanced nuclear technology, and, you know, I'd start with Ms.

Taylor but just welcome your thoughts as we leave here, what specific programmatic areas would you really like to see an increased focus from the Federal side, you know, where we can really catalyze some activity and I—you know, the electric power research industry I imagine you're pretty close to that. What would you recommend that we take back as we think about what we're going to fund in——

Ms. TAYLOR. Well, I'll——

Mr. CASTEN [continuing]. Upcoming budget cycles?

Ms. TAYLOR. I'll speak to a couple things. One is to recognize that there is a strong link between a lot of the research that's needed for advanced reactors and the plants that are operating today. So, for example, in the area of advanced technology fuel, we're looking at new materials that can make fuel more tolerant in the case of an accident, but then we're finding bringing in some of the concepts from the advanced reactors of going to higher enrichment fuel, for example, can bring nearer-term economic benefits to the plants today while readying the regulator, the supply chain, and the designers for the plants of tomorrow. So I think there's a lot of opportunity in that space. What are those things that can be accelerated to help accelerate the availability of advanced reactors while potentially bringing value to plants today?

The adoption of all the modern technologies that are going on in the world around us to these existing plants is an area where there's big opportunity for, you know, sensors, monitoring, data analytics, using things like drones and robotics for inspections all help bring, you know, better operation today and ready the future for the designers and the regulatory aspect, which is important and probably a critical path to the commercial availability of advanced reactors.

Mr. CASTEN. Yes.

Dr. LYONS. I certainly agree with the comments from Ms. Taylor, but let me just added another very strong need in this country, as you look at the advanced reactor concepts, is for testbed capabilities for those reactors. For example, I mentioned TerraPower earlier and Mr. Gates. They had to go to Russia to get some of their test capabilities because we don't operate a fast spectrum reactor in this country. One of the projects that is now being seriously considered within the DOE and Congress is the so-called Versatile Test Reactor, which would be a fast reactor. It would return the U.S. to a leadership position in fast reactors, a position we held in earlier decades.

So there definitely are testbed requirements, but as you look toward the advanced reactors, with nonlight water coolants, there are very definite needs for advanced test capabilities. These would logically be built at some of the national laboratories that have the expertise to build and operate such facilities. It would then be available to a vast number of advanced reactor startup companies around the country that need these test capabilities.

Mr. CASTEN. Thank you.

Chairman LAMB. OK. Thank you. Before we bring the hearing to a close, I just wanted to say two more thank yous. We are here in this room right now because of the kindness and generosity of the people of Shippingport, who have welcomed us today. So to any

Shippingport residents or local elected officials or, you know, government officials that are with us today, thank you for having us. We do have two members of local law enforcement with us in the back who have been watching over us the whole time and standing while doing so, so thank you, gentlemen, for doing that and for keeping us safe.

And then finally, I wanted to recognize we have several staff Members from Congress in attendance with us today, too, you can see at the table here and one behind me, and they're really the people that make Capitol Hill run every day, and they made sure that this place was all set up perfectly and ready to go. They prepare us, they get us where we need to go on time, pretty much always behind-the-scenes. The members of my congressional office are the same way. There are several of them all across the back of the room. So I just wanted you to know the major, major contribution that they make in making your government work every day and making hearings like this happen day in and day out in Washington, DC. and here. So we're very thankful for—to all of them for their work in getting us here and making this possible.

With that, the record will remain open for 2 weeks for any additional statements by the Members and for any additional questions the Committee may ask of the witnesses.

The witnesses are now excused with a final thank you from us for your participation, and the hearing is now adjourned.

[Whereupon, at 12:02 p.m., the Subcommittee was adjourned.]

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