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ADVANCED NUCLEAR TECHNOLOGY: SAFETY AND ASSOCIATED BENEFITS OF LICENSING ACCIDENT TOLERANT FUELS FOR COMMERCIAL NUCLEAR REACTORS

HEARING

BEFORE THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS UNITED STATES SENATE

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

SEPTEMBER 13, 2018

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COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

ONE HUNDRED FIFTEENTH CONGRESS
SECOND SESSION

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C O N T E N T S

ADVANCED NUCLEAR TECHNOLOGY: SAFETY AND ASSOCIATED BENEFITS OF LICENSING ACCIDENT TOLERANT FUELS FOR COMMERCIAL NUCLEAR REACTORS

THURSDAY, SEPTEMBER 13, 2018

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, DC.

The Committee met, pursuant to notice, at 10:03 a.m. in room 406, Dirksen Senate Building, Hon. John Barrasso (Chairman of the Committee) presiding.

Present: Senators Barrasso, Inhofe, Wicker, Ernst, Carper, Cardin, Whitehouse, Gillibrand, and Van Hollen.

Senator BARRASSO. Good morning. I call this hearing to order.

Before we begin today's hearing, I would like to say just a few words about America's Water Infrastructure Act.

This week we were able to reach a bipartisan agreement with the House of Representatives on major water infrastructure legislation. America's Water Infrastructure Act answers President Trump's call to address our Nation's aging infrastructure.

In this instance, the bill fixes America's water infrastructure. It authorizes important projects to deepen nationally significant ports, upgrades levees and dams, maintains inland waterways and shipping lanes, increases water storage for the arid West, fixes aging irrigation systems, and enhances American made hydropower.

This is also the most significant drinking water infrastructure bill in decades. It authorizes both new and existing programs that will gives States and localities the ability to better address their drinking water infrastructure needs.

This legislation is especially important as Hurricane Florence threatens the East Coast. Provisions in this bill will boost flood control and increase water storage. Both are critical in the preparation for and response to major storms.

The House of Representatives plans to pass the legislation today. Then the Senate can take it up and send it to President Trump for his signature.

America's Water Infrastructure Act is a major infrastructure bill. It shows congressional commitment to heed the President's call for action on infrastructure. The next step is roads and bridges, surface transportation. I hope we can have the same bipartisan success when we address America's transportation infrastructure.

I would like to thank Ranking Member Carper, Subcommittee Chairman Inhofe, Subcommittee Ranking Member Cardin, the House Transportation and Infrastructure Committee Chairman Shuster, and Ranking Member DeFazio for all of their hard work on this bill.

At this time, I would like to invite Senator Carper for any additions you would make.

Senator CARPER. Thank you so much, Mr. Chairman.

I want to second the words of praise you have offered for our colleagues in the House, for our colleagues sitting to our left and to our right, Senators Cardin, Inhofe, and all of our staff.

People at home say to me—and I am sure they do in your States as well—why can't you just work together? Why can't you work together and get something done? One of the most important things we can do is create a nurturing environment for job creation and job preservation. A big piece of that is infrastructure. A big piece of transportation infrastructure is water infrastructure.

Thank you, Mr. Chairman, for your leadership. It has been a pleasure to work with you and your staff and our colleagues and their staffs in this effort.

As the Chairman mentioned, on Monday night we were able to reach an agreement with our counterparts in the House to advance America's Water Infrastructure Act of 2018, which the Chairman and I co-authored, with the invaluable help of both the majority and minority staffs of this Committee and our colleagues over the better part of this last year.

As you may recall, our bill was reported out of this Committee unanimously 21 to 0 a couple of months ago, and hopefully, it will receive the same kind of support in the House later today and then in the Senate in short order.

In the meantime, I would just like to highlight several especially noteworthy provisions in this bill that will make significant, positive differences in communities across the country, including many in my home State of Delaware, throughout the Delmarva peninsula, and well beyond our borders.

For the first time in over 20 years this bill reauthorizes the program that provides Federal funding to States to help clean up the water our families drink every day. The crisis that unfolded in Flint, Michigan, several years ago was both tragic and avoidable. We have seen it play out since in far too many States across this country.

In this bill, we are making clear that we have learned our lesson: that we need to devote more resources to the things that are most important, like making sure every parent—no matter what ZIP code they live in—can be confident that the water coming out of their tap is safe for their kids and them to drink.

Not only does this bill reauthorize this program, but we actually double its funding by fiscal year 2021 to the tune of nearly $2 billion. Importantly, this legislation also allows States that detect contaminants in drinking water to assist residents who depend on private wells for their drinking water, rather than a public drinking water source.

For example, one in six Delawareans—it is similar in other States as well—depend on private wells for their drinking water.

It is just not right that if contaminants end up in their water, through no fault of the citizens or the residents, those residents have to find a way to rectify that situation solely on their own. That is just not fair.

Our bill helps to change that by helping States test and treat underground sources of drinking water. Also of note, this bill authorizes investments in the waterways that keep this country moving, from the Ports of Wilmington to the Port of Mobile to the Port of New York and the Port of New Jersey.

Over 99 percent of U.S. overseas trade volume moves through waterways that the U.S. Army Corps of Engineers maintains. Think of that; 99 percent. Our bill will help to improve and expand the harbors, channels, and ports on which our economy depends.

With Hurricane Florence bearing down on the East Coast this week, I would be remiss if I did not briefly mention the important provisions in this bill that help coastal communities better prepare for increasingly powerful and frequently extreme weather events and enable those communities to rebuild more quickly after disaster strikes.

Most notably perhaps, in light of the avoidable devastation and tragedy we saw in the wake of Hurricanes Maria and Harvey, our bill allows for the investment of $100 million in repairing drinking water systems damaged by storms. It creates new programs to protect this critical part of our infrastructure from damage due to extreme weather events going forward.

While President Trump has made waves this week with his comments about his "unsung successes" in Puerto Rico where nearly 3,000 of our fellow Americans apparently lost their lives, we have been working hard to pass a bill that will help to ensure storm ravaged communities actually have the resources they so desperately need.

There is much more in this bill that is worth highlighting, and I am sure there will be time to do so in the days and weeks to come.

For now, I want to again thank our Chairman. I want to thank our colleagues, Senators Inhofe, Cardin and their staffs for their hard work throughout this process.

I also want to thank our friends in the House, Representatives Shuster, DeFazio, Walden, and Pallone, who were great partners in the House.

Together, we are stronger. When we are together, so is America stronger.

Last, I want to thank Secretary R.D. James, who sat right here where you sit, Ms. Taylor, several months ago for his confirmation hearing to be the Assistant Secretary to head the Army Corps of Engineers, who made this legislation a real priority and worked with the Senators on this Committee to craft a bill that I think we can all be proud of.

I will end with an African proverb that I think is particularly relevant here: "If you want to go fast, go alone. If you want to go far, go together."

I think the fact that we have gotten a bill as substantive as this one to this point is proof that, in this Congress, if you want to get

meaningful work done, you have to find some common ground and find ways to work together. Kudos to everyone.

As we say in the Navy, when something good is happening, "Bravo, Zulu."

Thank you.

Senator BARRASSO. Thank you so much, Senator Carper, for all your cooperation. As you say, 21 to 0 in this Committee.

Senator Inhofe, as Chairman of the Transportation and Infrastructure Subcommittee, is there anything you would like to add?

Senator INHOFE. No, I don't think so, but one of the best kept secrets in America is that Oklahoma is navigable. The NCARNS, we have that reauthorization assured even though we have fallen behind. A lot of good things have not been mentioned that are a part of this.

Senator BARRASSO. Senator Cardin.

Senator CARDIN. I just really want to add that under Senator Barrasso's and Senator Carper's leadership, our Committee worked very constructively on this. Under Senator Inhofe, as Chair and Ranking Member, that was tradition in regards to the WRDA bill and was continued. I just wanted to acknowledge that.

I also want to point out, Mr. Chairman, as I was walking over here, I was stopped by the National League of Cities. They wanted to lobby me on one issue, the passage of the WRDA bill. I gave a copy of the letter to Senator Carper.

I also want to acknowledge Secretary James, when he was here, made commitments to visit some of our major facilities. He went to Poplar Island with me. His engagement on this process was extremely valuable.

This bill—the Water Resources Development Act—is going to be important for our country. It is important in Maryland on the Chesapeake Bay and our efforts to clean up the Chesapeake Bay. It is important to Maryland for safe drinking water.

The work that is done here is important to help our schools and public facilities with the vast connections with regard to pipes that will no longer contain lead. It is important for our economy and what it does in regard to the Port of Baltimore, and by the way, other ports around the country and around Maryland.

I am very proud to be a part of this, and congratulations to all.

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

Senator BARRASSO. Thank you to all of you.

This morning we are here to examine the safety and other benefits associated with advanced nuclear fuels, known as accident tolerant fuels, ATF. Accident tolerant fuels are for commercial and nuclear power plants. These fuels have the potential to greatly increase the safety and performance in nuclear reactors.

When loaded into a reactor, this technology would further protect uranium from melting if a plant loses the ability to cool the fuel. In the event of an emergency, accident tolerant fuels would provide significantly more time for power plant operators to prevent the release of radioactive material.

Following the 2011 disaster in Fukushima, Japan, Congress established a research program at the Department of Energy to en-

courage the development of accident tolerant fuels. Seven years later we are approaching the critical window for nuclear power plants to reap the safety benefits of this technology.

In addition to safety benefits, accident tolerant fuels may also provide meaningful economic benefits. For example, these fuels would allow nuclear power plants to generate electricity more efficiently.

In doing so, the plants would reduce costs and generate less nuclear waste. To realize these benefits, these fuels must be developed, tested, licensed, and deployed commercially. The Nuclear Regulatory Commission plays the principle role in this process.

The NRC has the exclusive authority to license and regulate the civilian use of nuclear materials. Approving new nuclear fuels can be a challenge. The fuel vendors must first test the fuel in rigorous experiments. The NRC then must validate the results of these tests through highly complex computer modeling.

Finally, the NRC must ultimately license the new fuels for use in a power plant. The NRC, the Department of Energy, and the nuclear industry are all carefully considering ways to facilitate this work.

In April of this year the NRC Commissioners held their first public briefing on what needs to get done prior to licensing these accident tolerant fuels. The briefing helped the agency staff to develop a project plan for regulating accident tolerant fuels, which the staff issued earlier this month. Yesterday the NRC staff held a public meeting on the plan.

The private sector is also taking steps to deploy accident tolerant fuels on an aggressive schedule. Two fuel vendors have already loaded test materials into two reactors to gather critical data. This process is encouraging, though significant hurdles remain.

One of the hurdles is the permanent closure of the Halden Test Center, which Norway announced earlier this summer. Since 1958 the Halden Reactor provided critical information on nuclear fuels and materials to organizations within 19 countries, including the NRC, the Department of Energy, and the American fuel vendors.

The Halden Reactor would have provided key scientific data to assess the performance of accident tolerant fuels. The NRC, the Department of Energy, and the nuclear fuel vendors will now need to adjust their existing research plans. In spite of Halden's closure, it is imperative that the NRC and the private sector stay on schedule to make an accident tolerant fuel available commercially as soon as possible.

The operating licenses for over a third of our Nation's nuclear power plants will expire between 2025 and 2035. If accident tolerant fuels are available, American energy utilities will be able to reap their safety and economic benefits.

Such benefits may encourage utilities to make multiple, multimillion dollar investment decisions to extend the licenses for these nuclear power plants. These new technologies would also help keep Americans employed. That includes workers in my home State of Wyoming, which produces more uranium than any other State in the country.

Preserving America's nuclear fleet is not only good for the economy, but is also good for the environment. Nuclear power provides

a source of clean energy to millions of American families and businesses.

As this week's issue of The Economist explains, "Some environmental activists don't like this source of zero carbon energy, but nuclear power still provides more than twice as much electricity globally as wind and 5.5 times as much as solar."

I look forward to the discussions this morning.

I will now turn to Ranking Member Carper for an opening statement.

OPENING STATEMENT OF HON. THOMAS R. CARPER, U.S. SENATOR FROM THE STATE OF DELAWARE

Senator CARPER. I want to apologize to our witnesses. Normally, we call this a hearing, and that is for us to hear from you. Please bear with us as you hear from us for just a few more minutes, and then we will put on our listening ears.

Again, Mr. Chairman, thanks so much for convening this important hearing on advanced nuclear technologies, specifically accident tolerant fuels. I spent a lot of years in my life in the Navy and have a huge appreciation for nuclear on ships and submarines.

We were scheduled to have the christening of the USS *Delaware*, a fast attack, junior class nuclear submarine in Newport News this Saturday. It has been postponed until October for obvious reasons. I am one who fully realizes and understands the importance of nuclear energy done well and done safely.

I know my colleagues have heard me say this before, but I will say it again: I believe there are few environmental challenges more serious than climate change and the extreme weather associated with it.

Our leading scientific agencies, NOAA and NASA among them, tell us that climate change is causing rising global temperatures, rising sea levels, and extreme weather events. We witness them almost every month, sometimes every week. Weather events, like the massive Hurricane Florence, is expected to strike the East Coast in the next few days and threaten the lives and well being of millions of Americans.

NOAA also tells us that extreme weather events that have cost our country more than $1 billion apiece have doubled in frequency over the past decade, with $425 billion in losses occurring over the last 5 years. That is $425 billion with a B. Think about that.

Whether it is a drought, a forest fire in the West, a hurricane or a massive flood in the East, climate change results in lost income, damaged properties, and sadly, in some cases, lost lives.

As we send up prayers for those who live in Florence's path and who are preparing for this massive storm, our Federal Government has a moral responsibility, not only to help our communities be better prepared for climate fueled events, but to also address the root causes of these events.

To some of our friends across the aisle who are not yet ready to join the rest of us in addressing climate action, let me note that nuclear power is one of the many examples of how our Nation can combat climate change, and at the same time, grow our economy.

I want to say that again. Let me note that nuclear power is one of the many examples of how our Nation can combat climate

change, and at the same time, grow our economy. We can do both, and we must.

When nuclear power is produced responsibly, it does not emit carbon and reduces our reliance on fossil fuels. Our country can—and should—seize the opportunity to continue to use nuclear energy in our national energy mix.

Today, nuclear power provides about 20 percent of our Nation's energy, as well as 60 percent of our carbon-free electricity, but as we know, the nuclear industry still faces many challenges. We need to make sure reactors operate well and safely, especially in the event of extreme weather.

Take what happened in Fukushima: nuclear power can lead to devastating circumstances if the proper safety precautions are not in place, not up to date, or not adhered to. Safety must always be the top priority in our country's approach to improving nuclear energy.

Today's costs for safety precautions at existing reactors, along with the costs of construction, operation, and maintenance, can be expensive, especially when compared to the cost of other sources of energy, such as natural gas.

Fortunately, recent advancements in science allow us to build and operate advanced nuclear technology that is safer, cleaner, and cheaper. If we are smart, we will replace our aging nuclear reactors with this new technology.

As we will hear today, advanced nuclear technology could improve the safety and efficiency of our existing reactors over the next 5 years. Using new materials for our nuclear fuel rods in our existing reactors, known as accident tolerant fuel, may allow our existing reactors to avoid the danger of overheating during emergency situations, which is what happened at Fukushima.

At the same time, accident tolerant fuel could enable our current fleet of nuclear reactors to run more efficiently, and therefore, be more cost competitive. This is situation in which it is possible to do well and do good at the same time.

My colleagues know that I love win-win situations. They do, too. Accident tolerant fuel has the potential to be a great win, not only for the fight against climate change and severe weather, but for industry, American jobs, and most importantly, the safety of the American people. We might want to think of this as a win-win-win-win situation.

As companies make advances in technology, we need to make sure that our regulatory framework keeps pace. The Nuclear Regulatory Commission, NRC, is still considered the world's gold standard of nuclear regulatory agencies.

As science and technology evolve, so too must the NRC. However, as I said before, we cannot afford to cut corners when it comes to nuclear safety. I am interested—and I think we are interested—in hearing today how the Federal Government can ensure all the design testing needed is completed expeditiously to help inform the NRC licensing process.

We also need to make sure that the NRC has the resources it needs to review these new technologies and to ensure that our current nuclear reactor fleet remains safe.

In closing, let me add that I strongly believe Congress has a critical role to play in ensuring that our Nation invests wisely in clean energy. That includes finding ways to support advanced nuclear technologies, which allow our reactors to be safer, more resilient, and more efficient.

Advances in nuclear energy can help us attain a more nurturing environment for job creation along with cleaner air for our people and planet. That is a pretty good combination, one which most Americans would like to see us embrace, and I hope we will do just that.

Thank you so much.

Senator BARRASSO. Thank you, Senator Carper.

Senator INHOFE. Mr. Chairman, let me just make one comment.

We have been fighting this battle for a long time now. We know how long it takes new technology to move. When you look at countries like France and China, we have to figure out a way to do it faster. It is obviously an answer that we need to exploit.

Regretfully, we have all this competition for committees this morning, and I will not be able to stay, but to me, there is no single issue that is more important than this, further exploiting the opportunity to come up with the clean energy that is offered through our nuclear efforts.

Senator BARRASSO. Thank you, Senator Inhofe.

Thank you and welcome to all of our witnesses. We are delighted that you have joined us here today.

Today, we are joined by Raymond Furstenau, Director, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission; Tina Taylor, Deputy Chief Nuclear Officer and Senior Director of Research and Development, Electric Power Research Institute; John B. Williams, Nuclear Fuels and Analysis Director, Southern Nuclear Company; and Dr. Christina A. Back, Ph.D., Vice President, Nuclear Technologies and Materials, General Atomics.

I want to welcome all of you. I want to remind you that your full written testimony will be submitted for the official record. If you could, please keep your statements to 5 minutes so that we have time for questions.

I look forward to hearing your testimony if we could start with you, Mr. Furstenau.

STATEMENT OF RAYMOND FURSTENAU, DIRECTOR, OFFICE OF NUCLEAR REGULATORY RESEARCH, U.S. NUCLEAR REGULATORY COMMISSION

Mr. FURSTENAU. Good morning, Chairman Barrasso, Ranking Member Carper, and distinguished members of the Committee.

My name is Raymond Furstenau. I serve as Director of Nuclear Regulatory Research at the U.S. Nuclear Regulatory Commission. I am pleased to be here today to report to you on the status of our preparations to license the safe use of accident tolerant fuels.

I would like to start this morning by highlighting the NRC's commitment to enhancing our regulatory infrastructure to facilitate the safe use of new technologies.

A recent example of success in this area is the licensing of new facilities using novel technologies for the production of medical isotopes, an issue of national interest due to periodic shortages of ma-

terial used in diagnostic medical procedures for millions of Americans each year.

Accident tolerant fuel, or ATF, is another area of new technology, which has the potential to enhance safety at U.S. nuclear power plants. ATF is a category of new fuels for nuclear reactors that are expected to perform better than currently licensed fuels under transient and accident conditions.

The fuel in use today at U.S. nuclear reactors is comprised of uranium dioxide pellets, encased in a metallic cladding fabricated from a zirconium based alloy, and has remained largely the same over the past several decades.

This is a plastic mock up of a fuel rod. This is a little bit larger in diameter than an actual fuel rod. Inside the rod, the cladding is zirconium based. The uranium dioxide pellets are stacked in the fuel rods. In an actual reactor, active fuel is about 12 feet in length. There are hundreds of elements in a fuel assembly and about tens of thousands of these individual rods put into assemblies in a nuclear reactor.

We expect that near-term ATF designs, defined as the concepts that industry is pursuing for deployment by the mid-2020s, will have relatively small departures from today's nuclear fuel designs.

These small departures include specially designed additives to standard fuel pellets and robust coatings applied to the outside diameter of standard claddings intended to reduce corrosion, increase wear resistance, and reduce the production of hydrogen under high temperature, accident, conditions.

Nuclear fuel designs with an iron based alloy cladding, also offering improved corrosion resistance, will likely be submitted for NRC review shortly following these near-term designs.

In the longer term, we expect ATF concepts to be submitted for NRC review that utilize new fuel pellet materials that operate at lower temperatures than current uranium dioxide fuel pellets, and ceramic silicon carbide cladding, which potentially offers significantly improved performance under high temperature conditions.

We also expect solid metallic fuel ATF concepts, which offer lower operating temperatures and decreased consequences of cladding breaches, to be submitted for NRC review in the years ahead.

To varying degrees, each of these ATF designs is expected to offer power plant operators more flexibility in how they operate their plants and provide more robust performance during normal operations and under potential accident conditions.

Most notably, ATF designs may enhance the ability to mitigate accidents due to the additional time available to plant operators prior to the onset of potential fuel damaging conditions. ATF designs may also have the ability to reduce the amount of high level waste produced by operating reactors by permitting extended operation of fuel assemblies in the reactor core.

While the NRC can license these new fuels under the current regulatory structure, we are taking steps to make our processes more efficient and effective. To that end, the NRC has developed a project plan to prepare for both near-term and longer-term ATF designs. The plan addresses the complete fuel cycle, including fuel fabrication, fresh fuel transport in reactor requirements, and spent fuel storage and transportation.

Throughout development of the plan, we have had extensive engagement with our stakeholders including licensees, nuclear vendors, industry groups, non-governmental organizations, and our international counterparts. Some of those stakeholders are on the panel today.

The plan outlines a new regulatory approach to fuel licensing, in which the NRC is seeking engagement with potential ATF applicants much earlier in the research and development phase than it has in the past.

This early engagement is designed to identify potential safety issues as early as possible so they can be addressed and the overall safety conclusions can be reached within the planned licensing timeline.

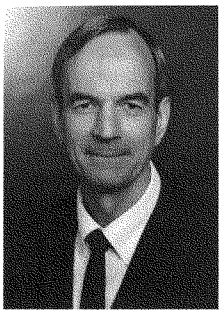
Throughout our preparations, we are monitoring the Department of Energy's efforts to advance the technical basis of ATF, both experimentally and computationally. This close coordination is allowing the NRC and DOE to make progress despite the closure of an internationally funded nuclear fuel and materials research facility, the Halden Reactor in Norway.

The NRC and DOE staffs are also working on ways to leverage DOE's testing capabilities and computational tools for use in reaching our safety findings for ATF designs without compromising the agency's regulatory independence.

In conclusion, with the issuance of the staff's ATF project plan and the heightened engagement of nuclear fuel vendors, DOE, and licensees, I believe the NRC has positioned itself well to efficiently license the safe use of ATF.

Thank you.

[The prepared statement of Mr. Furstenau follows:]



Raymond Furstenau
Director
Office of Nuclear Regulatory Research
Nuclear Regulatory Commission

Raymond Furstenau began serving as the Director, Office of Nuclear Regulatory Research (RES) on July 3, 2018. Prior to joining the Nuclear Regulatory Commission, Mr. Furstenau held several technical and leadership positions in the U.S. Department of Energy (DOE) from 1987 to 2018. During most of those 30+ years, he provided Federal oversight of nuclear facility operations and nuclear energy research & development programs at the Idaho National Laboratory. Mr. Furstenau transferred from DOE's Idaho Operations Office to Washington, DC in 2015 and served as Associate Principal Deputy Assistant Secretary in DOE's Office of Nuclear Energy.

Mr. Furstenau holds a B.S. degree in Applied Science and Engineering from the U.S. Military Academy and served as an active duty and reserve Army officer. He also received a M.S. degree in Nuclear Science and Engineering from Idaho State University and is a registered professional nuclear engineer.

WRITTEN STATEMENT
BY RAYMOND FURSTENAU, DIRECTOR OF NUCLEAR REGULATORY RESEARCH
UNITED STATES NUCLEAR REGULATORY COMMISSION
TO THE
SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
SEPTEMBER 13, 2018

Good morning, Chairman Barrasso, Ranking Member Carper, and distinguished members of the Committee. My name is Raymond Furstenau, and I serve as Director of Nuclear Regulatory Research at the U.S. Nuclear Regulatory Commission (NRC). I am pleased to report to you on the status of our preparations to license the safe use of accident tolerant fuel.

The NRC is an independent Federal agency established to regulate commercial nuclear power plants; research, test, and training reactors; nuclear fuel cycle facilities; and radioactive materials used in medicine, in academia, and for industrial purposes. I would like to start by highlighting the NRC's commitment to enhancing our regulatory infrastructure to facilitate the safe use of new technologies. An example of success in this area is the recent licensing of new facilities using novel technologies for the production of medical isotopes, an issue of national interest due to periodic shortages of material used in diagnostic medical procedures for millions of Americans every year.

Accident Tolerant Fuel, or ATF, is another area of new technology, which has the potential to enhance safety at U.S. nuclear power plants. ATF is a category of new fuels for nuclear reactors that are expected to perform better than currently licensed fuels under transient and accident scenarios. The fuel in use today at U.S. nuclear reactors is comprised of uranium dioxide fuel pellets, encased in a metallic cladding fabricated from a zirconium-based alloy, and has remained largely the same over the past several decades. We expect that near-term ATF designs, which are the concepts that industry is pursuing for deployment by the mid-2020s, will

have relatively small departures from today's nuclear fuel designs. These departures include specially designed additives to standard fuel pellets and robust coatings applied to the outside diameter of standard claddings intended to reduce corrosion, increase wear resistance, and reduce the production of hydrogen under high temperature (accident) conditions. Nuclear fuel designs with an iron-based alloy cladding, also offering improved corrosion resistance, will likely be submitted for NRC review shortly following these near-term designs.

In the longer term, we expect ATF concepts to be submitted for NRC review that utilize new fuel pellet materials that operate at lower temperatures than current uranium dioxide fuel pellets, and ceramic silicon carbide cladding, which offers significantly improved performance under high temperature conditions. We also expect solid-metallic fuel ATF concepts, which offer lower operating temperatures and decreased consequences of cladding breaches, to be submitted for NRC review in the years ahead.

To varying degrees, each of these ATF designs is expected to offer power plant operators more flexibility in how they operate their plants and provide more robust performance during normal operations and under potential accident conditions. Most notably, ATF designs will enhance the ability to mitigate accidents due to the additional time available to plant operators prior to the onset of potential fuel-damaging conditions. ATF designs also have the ability to reduce the amount of high-level waste produced by operating reactors by permitting extended operation of fuel assemblies in the reactor core.

While the NRC can license these new fuels under the current regulatory structure, we are taking steps to make our processes more efficient and effective. To that end, the NRC has developed a project plan to prepare for both near-term and longer-term ATF designs. We began the development of this project plan within the current regulatory framework in order to optimize

timing and resources and with the confidence that our regulations provide the appropriate starting point and flexibility to accommodate accident tolerant fuel designs. We believe the existing regulatory framework is largely compatible with the current near-term accident tolerant fuel concepts. For example, Southern Nuclear's Hatch reactor in Georgia has recently loaded a limited number of testing samples of a near-term ATF design under its current operating license and the NRC's existing regulatory framework. Consistent with our Principles of Good Regulation and based on our interactions with Southern Nuclear throughout that process, the NRC has decided to more clearly document our regulatory positions on this practice to offer enhanced regulatory stability as industry seeks to obtain operating experience with ATF designs. The industry has safely used these types of targeted programs for decades, and the NRC recognizes that fuel performance data collected in commercial reactors through this testing plays an important role in making the safety case for new fuel designs.

The NRC's ATF project plan addresses the complete fuel cycle, including consideration of fuel fabrication, fresh fuel transport, in-reactor requirements, and spent fuel storage and transportation. The plan also includes an acknowledgement of the consideration for operational flexibilities that licensees may seek based upon the additional safety margin provided by ATF designs. Throughout the development of the plan, we have had extensive engagement with our stakeholders, including licensees, nuclear fuel vendors, industry groups, non-governmental organizations, and our international counterparts.

The plan outlines a new regulatory approach to fuel licensing, in which the NRC is seeking engagement with potential ATF applicants much earlier in the research and development phase than it has in the past. This early engagement is designed to identify potential safety issues as early as possible so they can be addressed and the overall safety conclusions can be reached within the planned licensing timeline. Data sharing and engagement during the research and

development phase facilitates efficiency in the later licensing phase. The NRC will also be refining its regulatory infrastructure, informed by significant communication with our stakeholders such that transparency is maintained and regulatory expectations are clearly communicated to the applicant as early as possible in the process.

Throughout our preparations, we are monitoring the Department of Energy's (DOE's) efforts to advance the technical basis for ATF, both experimentally and computationally. We have added ATF-specific addenda to our memorandum of understanding with the DOE, which allows us to engage with the department on planned testing of accident tolerant fuel designs under normal operations and accident conditions, as well as efforts to develop and validate the appropriate data required to model accident tolerant fuel. This close coordination is allowing the NRC and DOE to make progress despite the closure of an internationally funded nuclear fuel and materials research facility, the Halden Reactor in Norway. Additionally, the NRC staff is closely following a DOE-led effort to assess and make recommendations for irradiation testing for ATF at alternate facilities such that the timeline for ATF deployment is not impacted.

The NRC and DOE staffs are also working on ways to leverage DOE's computational tools for use in reaching our safety findings for ATF designs. Based on the information we have so far, we believe that for near-term ATF concepts, it will be most efficient and effective for staff to use existing NRC computational tools, which can be modified with minimal effort and for which the staff have extensive experience and confidence. For longer-term concepts, which require greater effort to adapt existing NRC computational tools, DOE's unique and advanced modeling capabilities are being evaluated for NRC use.

In conclusion, with the issuance of the staff's ATF project plan and the heightened engagement with nuclear fuel vendors, DOE, and licensees, I believe the agency has positioned itself well to license the safe use of ATF in an efficient manner.

Senate Committee on Environment and Public Works
Hearing entitled, *"Advanced Nuclear Technology: Safety and Associated Benefits of Licensing Accident Tolerant Fuels for Commercial Nuclear Reactors"*
September 13, 2018
Questions for the Record for Mr. Furstenau

Chairman Barrasso:

QUESTION 1. **Last year, the Nuclear Regulatory Commission (NRC) established a steering committee to develop a strategy to license and deploy accident tolerant fuels (ATF).**

a) Please list all the offices and each office's representative involved with the ATF steering committee (ATF SC).

b) Please define the respective roles of those offices.

c) Who leads the steering committee?

d) How will the leader of the steering committee manage and coordinate with staff in other NRC offices?

ANSWER.

a, b, c) The table below lists the office and division representation on the NRC's ATF SC and the respective role of each member. The ATF SC is led by the Director of the Division of Safety Systems in the Office of Nuclear Reactor Regulation, currently Dr. Mirela Gavrilas. It should be noted that membership of the ATF SC is defined by position, Division Director or Deputy Division Director of each Division listed on the table, and does not follow specific individuals.

Office	Division	Role
Office of Nuclear Reactor Regulation	Division of Safety Systems	Chair; manages the review of fuel designs and plant systems.
	Division of Risk Assessment	Manages risk assessment & severe accident activities associated with ATF.
	Division of Operating Reactor Licensing	Manages the review and processing of plant specific licensing actions related to ATF.
	Division of Licensing Projects	Manages the review and processing of topical reports related to ATF.
Office of Nuclear Regulatory Research	Division of Systems Analysis	Manages the response to research needs for ATF and maintains fuel and accident analysis tools/codes.
Office of Nuclear Material Safety and Safeguards	Division of Fuel Cycle Safety, Safeguards and Environmental Review	Manages the review of ATF impacts on fuel fabrication facilities.
	Division of Spent Fuel Management	Manages the oversight of transportation and storage of nuclear fuel.
Office of New Reactors	Division of Safety Systems, Risk Assessment and Advanced Reactors	Manages the oversight of ATF impacts on new reactors, insights from preparations to license advanced reactors, and risk assessment activities.

d) The leader, or chair, of the ATF SC manages and coordinates with staff in other NRC offices through the SC to ensure progress and implementation of the NRC's ATF Project

Plan to prepare for efficient and effective licensing of ATF.[1] Steering Committee meetings are generally held on a monthly basis, or more frequently based on current events, to discuss the status of ATF working group activities and ATF activities external to the NRC, such as those of industry and the U.S. Department of Energy. The project plan is a living document that may evolve as (1) ATF concepts are more clearly defined, (2) schedules are refined, (3) the knowledge level of specific concepts increases as experimental testing programs are completed, and (4) potential extensions to the current operating envelope of fuel are identified. As the ATF SC begins to implement the ATF Project Plan, the team will be re-assessing the roles and responsibilities of the SC to ensure it continues to provide a structure for success.

QUESTION 2. **The NRC Commissioners are currently reviewing staff recommendations on what is known as the "NRC Transformation Initiative." To what extent does the NRC's ATF project plan incorporate staff recommendations into the Transformation Initiative?**

ANSWER.

The NRC Executive Director for Operation's report to the Commission on the transformation initiative stated that the agency's ongoing initiatives related to ATF, "in combination with the approaches in the staff's recommended licensing strategy to appropriately focus on more safety significant issues and use existing information, will ensure that the NRC is prepared to review

[1] The ATF Project Plain is available in the NRC's Agencywide Documents Access and Management system (ADAMS) at Accession No. ML18261A412.

applications for the use of ATF in a timeframe that supports the industry's current timelines for development of the fuel."[2]

In reaching this conclusion, the team that developed the report recognized that the NRC's ATF project plan outlines a new paradigm for fuel licensing that allows for the steps of the fuel development and licensing process to be completed in parallel, as opposed to in series, as has been done in the past. This approach has the potential to enable significant schedule efficiency for the time between the completion of the technical basis to support a safety finding and the licensing of the fuel for use at U.S. nuclear power plants. The plan was developed through extensive internal and external stakeholder interaction to ensure that best practices from within the agency and the nuclear industry as a whole were taken into account.

QUESTION 3. **The NRC is simultaneously reviewing multiple new fuel types and reactor designs.**

a) How is the Commission using "risk-informed analyses" to outline its safety priorities during the licensing process and make clear to applicants what information is required?

b) What steps is the NRC taking to ensure the process is clear and expeditious, while balancing safety interests?

ANSWER.

a) The NRC uses a risk-informed approach to regulation by taking into account both the probability of an event and its possible consequences to understand its importance (risk). To estimate risk, the NRC uses probabilistic risk assessment (PRA) methods in

[2] Enclosure 1 of SECY-18-0060 "Achieving Modern Risk-Informed Regulation" (ADAMS Accession No. ML18110A186).

regulatory matters to the extent supported by the state-of-the-art in PRA technology and data. PRA methods complement the NRC's deterministic approach (based on experience, test results, and expert judgment) and support the NRC's traditional defense-in-depth philosophy, consistent with the Commission's policy statement[3] on the use of PRA in nuclear regulatory activities.

To ensure applicants understand what information is necessary to meet regulatory requirements, the NRC staff seeks to issue guidance in all practical areas. Where applicable, publicly available guidance documents outline how the NRC staff uses risk-informed analyses to inform its actions. One example of a significant guidance document that does so is NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition" (available at https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0800/). As noted in the introduction to NUREG-0800, the staff may adjust the depth of review for a particular topic based on risk insights, among other considerations. In addition, the Office of New Reactors has applied a safety-focused review approach to the design certification review for the NRC's first application for a small modular reactor (NuScale), in order to better balance the level of staff review with the associated safety significance.

To communicate to the public at large how risk information is used in a variety of regulatory applications, the NRC maintains information on risk-informed activities in the reactor, materials, and waste areas on its public web site. In addition, the NRC holds periodic Risk-Informed Steering Committee public meetings with industry

[3] 60 FR 42622 "Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities; Final Policy Statement" (https://www.nrc.gov/reading-rm/doc-collections/commission/policy/60fr-42622.pdf)

representatives and other stakeholders to discuss the status and priority of risk-informed initiatives and processes.

b) The NRC's Principles of Good Regulation (available at https://www.nrc.gov/about-nrc/values.html) guide the staff in carrying out our regulatory activities. These principles focus the staff on ensuring safety and security while appropriately balancing the interests of the NRC's stakeholders, including the public and licensees. Our principles include independence, openness, efficiency, clarity, and reliability.

In accordance with the Principles of Good Regulation, the staff has developed and issued the NRC's ATF Project Plan to prepare for efficient and effective safety reviews and licensing decisions for ATF. The plan lays out a new paradigm for fuel licensing that has the potential to enable significant schedule efficiency. It also includes several additional deliverables for the NRC staff, including phenomena identification and ranking table (PIRT) exercises, and development of concept-specific licensing roadmaps, which will enhance clarity for licensees and applicants as the technical basis and development timeline for each ATF concept continues to progress. Early alignment between the NRC staff and stakeholders on the phenomena important to safety for each ATF design will ensure that applicants understand the testing needs and justifications necessary to allow the NRC to reach a safety finding. The additional deliverables will also require public interactions to allow interested parties to provide feedback to the staff in all areas, including clarity, efficiency, and safety. Following the PIRT exercise for each ATF concept, the staff will develop concept-specific licensing roadmaps that outline, for each individual concept, a pathway for meeting the regulatory requirements necessary for licensing.

The development of the ATF Project Plan has been transparent. The plan was issued for public comment in the *Federal Register*, the NRC held four public meetings on the plan over the past year, and staff briefed the Commission and the NRC's Advisory Committee on Reactor Safeguard's Subcommittee on Metallurgy and Reactor Fuels on draft versions of the plan. This has provided stakeholders with opportunities to provide feedback to the staff on ATF activities.

Also, with regard to the development of ATF, based on stakeholder feedback, the NRC staff is developing guidance to clarify when lead test assembly (LTA) programs require NRC staff review and approval prior to utilization in the reactor core. This draft guidance was published for public comment in June 2018 and is scheduled to be finalized in early 2019.

QUESTION 4. **How is the NRC collaborating with the Department of Energy (DOE) in modeling and simulating new fuel and reactor designs?**

ANSWER.

Over the past several years, the NRC staff has been working with the DOE to determine how best to leverage DOE's Consortium for Advanced Simulation of Light Water Reactors (CASL) and Nuclear Energy Advanced Modeling and Simulation programs for new fuel and reactor designs. With respect to CASL in particular, there are several areas where the DOE's modeling and simulation have been used to improve the NRC's confirmatory tools for safety and licensing reviews. The majority of the effort between the two programs has been in the areas of neutronics and nuclear data. For example, the Shift CASL code, which calculates radiation transport, is being integrated into the NRC-funded SCALE code to improve NRC's capability in

reference depletion calculations, criticality safety, and shielding analysis. The integration is expected to be completed by January 2019 and will improve calculations of reactor pressure vessel neutron fluences, which are used to estimate the neutron embrittlement of the reactor pressure vessel, a critical part of NRC's evaluation of proposed plant lifetime extensions.

More recently, on September 12, 2018, NRC staff met with DOE and representatives of the CASL program to continue collaborative efforts in evaluating DOE computer code capabilities for potential regulatory applications. NRC staff provided details of several specific regulatory applications where the enhanced computing capacity and lower-length scale modeling of DOE's advanced modeling and simulation tools could provide new insights for regulatory applications. These areas include the potential use of DOE codes to examine the applicability of traditional reactor core analysis methods for ATF and to gain insights into the performance of ATF that can be used as the staff considers refinements to the regulatory infrastructure (e.g., refining specified acceptable fuel design limits. DOE has indicated it will pursue a number of the NRC staff's suggested analysis areas in the upcoming fiscal year.

In addition, the NRC and DOE hold quarterly management meetings to identify areas of mutual interest requiring coordination. These meetings cover a range of topics, including activities associated with new and advanced reactor deployment and licensing and development of computational tools.

Senator Markey:

QUESTION 5. **One former NRC staff member wrote in a public comment on the NRC's proposal that, "The NRC's apparent willingness to abdicate the authority to review new fuel assembly designs, before they are**

utilized in the reactor core, is unwise and contrary to the goal of ensuring the safe use of radioactive materials in order to protect people and the environment." Do you agree with this comment?

ANSWER.

The NRC does not agree with this comment. The subject comment appears to reference the NRC's draft guidance on the licensing of lead test assemblies (LTAs). The nuclear industry has used LTAs for decades to collect prototypical reactor data to develop the safety case for larger, batch loading of new fuel assembly designs. LTA programs have been conducted through various existing regulatory pathways in the past. Some have been inserted, without the need for prior NRC staff approval, under the NRC change process regulations and in accordance with a provision in the plants' technical specifications, which place limitations on the quantity and location of lead test assemblies.

The draft guidance currently being developed by NRC will clarify when an LTA requires NRC staff review and approval prior to utilization in the reactor core. Regardless of whether prior NRC approval is required, the LTAs are still subject to all of the requirements imposed by the regulations, the license, and the technical specifications, including the NRC change control regulations that are subject to inspection through the Reactor Oversight Process. Because of these requirements, inspections, and operating experience, the NRC believes that the draft guidance approach for LTAs is consistent with our safety goals and with the NRC's Principles of Good Regulation.

QUESTION 6. **When the NRC conducts independent reviews, do those reviews lessen the risk that plant safety will be compromised?**

ANSWER.

For some proposed changes to their plants, licensees must submit applications to the NRC requesting approval to implement the modifications. In these instances, NRC staff performs independent confirmatory reviews and documents its findings in a safety evaluation to ensure that the proposed changes to the facility comply with the NRC's regulations, thereby meeting the NRC's mandate of ensuring reasonable assurance of adequate protection of public health and safety. In other circumstances, there are specific provisions that allow licensees to make changes to their licensing basis without prior NRC review and approval, provided those changes meet specified criteria that ensure safety. These situations are clearly defined in the regulations or within a facility's licensing basis (e.g., 10 CFR 50.59 and plant technical specifications). Operation of a plant within its licensing basis, as required, ensures safety and security of people and the environment.

In addition, the NRC's reactor inspection process, including resident inspectors stationed at every operating nuclear power plant in the U.S., and the Reactor Oversight Process, ensures that plants are meeting Federal safety requirements and operating within their licensing basis.

Senator BARRASSO. Thank you very much for your testimony. We will have questions in a little bit.

I would now like to turn to Ms. Taylor.

Thank you very much for joining us today.

STATEMENT OF TINA TAYLOR, DEPUTY CHIEF NUCLEAR OFFICER AND SENIOR DIRECTOR OF RESEARCH AND DEVELOPMENT, ELECTRIC POWER RESEARCH INSTITUTE

Ms. TAYLOR. Good morning, Chairman Barrasso, Ranking Member Carper, and members of the Committee.

My name is Tina Taylor. I am a Senior Director for Research and Development and Deputy Chief Nuclear Officer at the Electric Power Research Institute, EPRI. I am pleased to be here today to talk with you about EPRI's research related to accident tolerant fuels.

EPRI conducts research and development relating to the generation, delivery, and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings its scientists and engineers, as well as experts from academia, government, and the industry, to help address challenges related to 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, including all of the U.S. nuclear reactor operators.

For the past 30 years EPRI has conducted research on nuclear fuels for greater reliability, safety, and performance. Our research on ATF is focused on evaluating the safety and economic benefits. While we are not currently developing any ATF technologies, our work is informing strategic decisionmaking for ATF implementation.

Accident tolerant fuels have the potential to offer safety and environmental benefits with more resilient and efficient fuel and plant performance. Key improvements in ATF are higher melting temperatures, improved strength and toughness, reduced hydrogen generation, and better confinement of nuclear materials during postulated off-normal events. Additionally, ATF may also improve the underlying economics.

Getting these new technologies from design to implementation is challenging and involves the collaboration of many organizations. As you are hearing today, there is currently great collaboration underway between DOE, NRC, fuel vendors, industry, plant operators, the National Labs, EPRI, and others.

EPRI's research is focused on how ATF performance improvements translate into providing more plant resilience to off-normal events and economic benefits during normal operation.

In 2017 EPRI performed an initial assessment of ATF. The performance of ATF concepts was evaluated for a number of scenarios. The work concluded that safety benefits do exist and vary among different ATF designs and plant designs.

Some ATF concepts may have mitigated the Three Mile Island II accident. Other accident scenarios we evaluated showed that accident tolerant fuels have the potential to provide additional coping time.

A critical metric for decisionmakers is ATF deployment timeframes. The sooner these ATF concepts can be deployed, the sooner the safety and economic benefits will be realized. Historically, the licensing of new fuels and cladding has taken upwards of 20 years.

EPRI is researching approaches that could shorten this timeframe. Advanced modeling and simulation with modern data collection methods may be useful to reduce the number of time consuming and costly tests that are needed. Development of new examination techniques may allow quicker results from the tests that are performed.

In conclusion, accident tolerant fuels have the potential to provide increased safety margins over current nuclear fuels while also providing enhanced fuel reliability, improved economics, and reduced high level waste generation. Working collaboratively with the other stakeholders, EPRI will continue to conduct technical evaluation of accident tolerant fuels in order to provide information needed to establish criteria, provide safety analysis, and identify economic benefits.

I thank you for the opportunity to testify this morning. I am happy to answer your questions.

[The prepared statement of Ms. Taylor follows:]

Tina M. Taylor
Deputy Chief Nuclear Officer
Senior Director, Research and Development
Electric Research Power Institute

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.

Hearing of the U.S. Senate Committee on Environment and Public Works

Tina Taylor
Senior Director Research & Development, Deputy Chief Nuclear Officer,
Nuclear Sector, Electric Power Research Institute

"Hearing to explore the safety and associated benefits of licensing accident tolerant fuels for commercial light-water reactors and advanced nuclear reactors."

September 13, 2018

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 today's testimony is EPRI's collaborative research efforts related to Accident Tolerant Fuels (ATF). ATF has the potential to offer significant safety, environmental, and economic benefits. Bringing ATF technologies from design concept to implementation is challenging and involves the collaboration of many governmental, public, and private stakeholders. This testimony provides an overview of EPRI's research activities related to the potential benefits from ATF as well as the support needed to accelerate further development and implementation.

In the wake of the 2011 Fukushima accident, the priority of accelerating the research and development of ATF technologies was recognized by Congress, the Department of Energy (DOE), and the nuclear industry. As a result, the DOE initiated a ten-year program with the goal of inserting test rods with enhanced accident tolerance into a commercial reactor by 2022. With the strong support of the nuclear industry, this goal was achieved in early 2018 at Southern Nuclear's Hatch Power Plant, located in Baxley, Georgia. Hatch loaded two different ATF concepts for testing into the reactor, a first for the U.S. industry. This was a significant achievement, but technical and regulatory hurdles still remain if the U.S. is to achieve full-core ATF deployment by the mid-2020s. Traditionally, licensing of new fuels designs can take 20 years. In order to realize the benefits of accident tolerant fuels in a meaningful time frame, collaborative and innovative approaches are being leveraged.

Overview of Accident Tolerant Fuel

The U.S. nuclear industry has been aggressively pursuing ATF concepts with the goal to improve performance during normal operations and accident conditions and to deploy these fuels by the early to mid-2020s.

Accident tolerant fuels are defined as fuels that can tolerate a loss of active cooling in the core for a longer time period than current fuel options, while maintaining and improving fuel, system, and plant performance during normal operation. The potential for ATF is to provide more resilient performance during hypothetical accident scenarios while providing more efficient performance during normal operation.

Key ATF targeted parameters under consideration and development include:

- Decreased corrosion rates
- Higher melting temperatures
- Reduced hydrogen generation during postulated accidents
- Improved strength, toughness, and high temperature behavior
- Enhanced behavior to ramp more quickly for flexible power operations
- Better confinement of radioactive materials during postulated accidents
- Improved resistance to wear and foreign material damage

The ATF concepts under active development can be divided into two categories: near-term and longer-term concepts, based on their anticipated timeline to full core deployment. Near-term concepts can use the current licensing structure with current regulations and regulatory guidance to allow for licensing of these ATF concepts. These near-term concepts are expected to be commercially viable for full-core deployment by the mid-2020s. Longer-term concepts have more gaps in data, regulatory acceptance criteria, limiting regulations and regulatory guidance. As a result, these concepts are expected to take a longer period of time to develop and license prior to full-core deployment in operating commercial reactors.

Whether ATF is adopted by commercial reactor operators will be a business decision. EPRI's research plays a role to inform key industry decision-makers on the potential ATF safety and economic benefits for their plants. A critical metric for the industry decision-makers is ATF deployment timeframes. The sooner these ATF concepts can be deployed, the sooner the safety and economic benefits will be realized. Historically, the licensing of new fuels and cladding within the current regulatory infrastructure has taken upwards of twenty years. An expedited approach to reduce licensing timeframes could lead to quicker deployment of these new fuels.

The research, development, licensing, and deployment of ATF represents a substantial investment and collaboration among fuel vendors, operating utilities, research institutions, regulatory authorities, and other governmental agencies. Substantial safety and economic benefits may be required to justify the adoption and wide-spread implementation of the new fuel technologies, e.g., increased safety margins, enhanced fuel reliability, improved economic benefits, optimized fuel cycle operational strategies, and reduced waste generation.

EPRI Research and Development

EPRI has been conducting research over the past 30 years on advanced fuels seeking greater reliability, safety, and performance. During that time, EPRI has collaborated with key domestic governmental and commercial stakeholders to conduct research and development activities to inform fuel reliability, performance, cost-savings, efficiencies and safety.

In the late 1990s, EPRI created its Robust Fuel Program to assess high burnup fuels under normal reactor operations and postulated accident scenarios. This work has also informed the dry storage and transportation of high burnup fuel. In the early 2000's, the focus of EPRI's research shifted to improved fuel reliability and operational issues to reduce fuel failures.

Recently, EPRI fuel programs have focused research efforts to inform further potential safety and economic benefits of ATF technologies, higher uranium enrichments and discharge burnups. While EPRI is not currently developing any ATF technology, it is informing public and private stakeholders with key safety, economic, and operational technical analyses to support strategic decision-making for potential ATF implementation.

The Potential Benefits of ATF Technologies

The early adoption of ATF by commercial reactor owners/operators is predicated on the need to assess the potential benefits from ATF and the associated implementation costs. In 2017, EPRI performed an initial assessment of expected ATF performance. This work was done to assess and quantify the various safety enhancements offered by various ATF concepts. For the initial ATF safety impacts assessment, the performance of each ATF concept was evaluated for a number of postulated accidents. These assessments consisted of performing safety analyses for key accident sequences and comparing the ATF results against those obtained for the same events calculated using current zirconium uranium oxide fuel designs.

At this stage of ATF development, there are significant uncertainties associated with the proposed ATF concepts. The analysis will need to be updated as additional test data become available. The key conclusions from EPRI's initial ATF study include:

- Safety benefits exist and vary among the different ATF concepts and plant characteristics
- Specific ATF concepts may have limited the Three Mile Island-2 core damage
- Other accident scenarios that were modeled showed that accident tolerant fuels have the potential to provide additional coping time

EPRI is conducting a second study to build on the initial results. The current work includes additional accident scenarios, fuel cycle optimization (increased enrichment and discharge burnups) assessments, and exploration of additional benefits not previously studied. These efforts have identified three major areas of potential economic benefits that can result from more resilient ATF fuels including:

- Increased fuel reliability

- More efficient fuel cycles that could also reduce the amount of generated waste
- More robust fuel performance leading to improved operational flexibility

These potential benefits could provide plant operational performance enhancements and/or substantial cost reductions and/or plant operational performance enhancements.

ATF concepts potentially include more durable materials that may provide better fuel reliability. These innovative designs and materials may provide enhanced reliability by reducing possible fuel failures and preventing the potential for plant shutdowns. Fuel cycle optimization through higher enrichments and discharge burnups would allow for improved fuel efficiencies.

Improved ATF material performance enables the potential for higher discharge burnups which provides the potential for higher enrichments and improved fuel cycle efficiencies. This may allow certain plants to go from 18 to 24-month fuel reloading which could reduce the amount of fuel needed, thereby, reducing the amount of waste generated.

Moreover, the enhanced ATF fuel performance could also lead to greater operational flexibilities which could improve integration of nuclear plants with other non-CO_2 emitting electricity generating sources. EPRI plans to evaluate enhanced flexible power operations in the near future. EPRI also plans to finalize a report in early 2019 documenting the safety benefits results that could lead to these economic benefits.

Innovations for Accelerated Implementation

Traditionally, qualification and licensing of new fuel designs has taken over twenty years. Innovative approaches can collect test data more rapidly and efficiently than the current paradigm of irradiation tests followed by destructive post-irradiation examinations at domestic and international hot cells. The time required to irradiate, cool down (for transportation), transport from irradiation facility to hot cell, and destructively test at the hot cell takes several years for each test. Several such tests have been carried out to demonstrate safety for new fuel licensing in the past, leading to the greater than twenty-year design-to-licensing timeframes for new fuels. Alternative advanced data collection methods could shorten this timeframe by collecting data in situ or without destructive examinations using sophisticated non-destructive techniques, which could reduce the transportation and destructive examination steps. EPRI is working to develop non-destructive examination techniques that could lead to quick data collection without the need for shipping and destructive examination.

Advanced modeling and simulation (M&S) along with new expedited experimental data collection methods through advanced sensors and non-destructive evaluation techniques could be used to provide sufficient technical information to support ATF implementation. The development of advanced M&S can facilitate ATF implementation with key support to utilities and vendors on design considerations, normal operation evaluations, ATF fuel performance assessments, and for licensing. Enhanced capabilities of advanced M&S, combined with targeted experimental data, can help provide confidence in the designs of ATF technologies.

The use of these new data collection and modeling tools can reduce the time and cost of introducing innovative technologies into operating nuclear plants by reducing the number of time-consuming and costly tests and demonstrations, potentially addressing one of the major hurdles in getting ATF to market sooner. A focused collaboration between the U.S. industry, EPRI, DOE, and NRC can help expedite the implementation of ATF concepts.

Current regulations are focused and fixed to the current fuel systems which are also applicable to the near-term ATF concepts. However, the lack of licensing acceptance criteria and regulatory expectations for longer-term ATF concepts limit vendors to develop experimental test plans and licensing strategies. The need for regulatory clarity and predictability can be alleviated through a collaborative process involving the key stakeholders to collectively identify and align on the gaps in regulatory acceptance criteria and data related to various fuel designs. This gap identification process involves working with technical regulatory specialists and subject matter experts to identify and define the key knowledge gaps in test data, modeling, licensing methodologies, regulations, and guidance. This effort can help prioritize the work to be done to fill the gaps, help all stakeholders align on a schedule and improve certainty in the process.

Irradiation Testing Facilities

Test reactor irradiations are traditionally and important step in the development of new fuels. In the past year, the nuclear industry lost a key asset in the Halden test reactor which had been operated since 1958 at the Norwegian Institute for Energy Technology (IFE) and funded by 19 countries under the Organisation for Economic Co-operation and Development Nuclear Energy Agency (OECD/NEA).

The DOE is in the process of defining the path forward without Halden. At this point, there does not seem to be a significant delay for the near-term ATF concepts. For the longer-term needs, EPRI is working with key domestic and international (OECD/NEA) stakeholders to identify a long-term solution to provide irradiation test facilities that can support longer-term ATF concepts.

Halden had unique capabilities for real-time monitoring and testing during irradiation while simulating the operating environments of existing U.S. reactors. All four vendors of ATF (Global Nuclear Fuels, Westinghouse, Framatome, and Lightbridge/Enfission) were current or prospective users of the Halden test reactor and hot cell facilities. Since Halden was scheduled to perform testing for all four U.S. ATF vendors, the unexpected loss of Halden will require some reconfiguration of the research and development plans in advance of commercial deployment of ATF.

Concluding Remarks

Accident Tolerant Fuels have the potential to provide increased safety margins over current nuclear fuels while also providing enhanced fuel reliability, improved economics through optimized fuel cycles, and reduced high-level waste generation. Accident Tolerant Fuels may enable utilities to realize additional economic and operational benefits from increased enrichments, higher

discharge burnups, and higher resiliency for more efficient operations and cost savings. EPRI will continue to conduct technical evaluation of accident tolerant fuels in order to provide information needed to establish criteria, provide safety analysis and identify economic benefits.

U.S. Senate Committee on Environment and Public Works
September 13, 2018 Hearing: ***Advanced Nuclear Technology: Safety and Associated Benefits of Licensing Accident Tolerant Fuels***
Questions for the Record Submitted by Ms. Tina Taylor

Question from Chairman Barrasso

Question 1:

The focus of the Department of Energy's public-private partnership to develop accident tolerant fuels is the deployment of this safer fuel in commercial nuclear power plants located in the United States. However, nuclear power is utilized around the world.

What are the potential global market opportunity for U.S.-based vendors if the NRC is the first regulator to approve and utilize safer nuclear fuels?

The U.S.-based fuel vendors currently sell fuel outside of the U.S. and are developing accident tolerant fuels for a global market. One of the fuel vendors already has a lead test rod in a commercial reactor in Switzerland.

The regulators in each country will develop their own criteria for licensing advanced fuel and will assess various technologies against that criteria. As the NRC reviews and possibly approves the use of accident tolerant fuels, international regulators will have access to this information and can factor that into their independent analysis. This may help speed up acceptance in other markets.

Senator BARRASSO. Thank you, Ms. Taylor. I appreciate your testimony.

Mr. Williams.

STATEMENT OF JOHN B. WILLIAMS, NUCLEAR FUELS AND ANALYSIS DIRECTOR, SOUTHERN NUCLEAR OPERATING COMPANY

Mr. WILLIAMS. Good morning.

I am John B. Williams, Nuclear Fuels and Analysis Director at Southern Nuclear Operating Company and am a member of the Nuclear Energy Institute's Accident Tolerant Fuel Working Group led by Mr. Danny Bost, Executive Vice President and Chief Nuclear Officer of Southern Nuclear.

Southern Nuclear, a subsidiary of the Southern Company, currently operates six nuclear reactors in Alabama and Georgia. Southern Nuclear embodies the Southern Company's commitment to creating America's energy future by developing new products and services for the benefits of consumers through technological innovation.

As such, we are proud to be taking a leadership role in the development and testing of accident tolerant fuel.

It is an honor to appear before this committee to share my views on the benefits of accident tolerant fuels and how we can overcome the development and licensing challenges before us.

I thank Chairman Barrasso, Ranking Member Carper, and the Committee members for taking the time today to discuss this pivotal technology that has the potential to make our Nation's nuclear fleet more reliable and efficient, as well as enhance its safety.

America's nuclear power plants run 24 hours a day, 7 days a week, providing 20 percent of the Nation's electricity and nearly 60 percent of its clean, emissions-free power. The nuclear fleet is a vital part of America's infrastructure and is essential to a reliable and resilient national grid.

The sustainability of the U.S. nuclear fleet will depend, in large part, on the industry's ability to innovate at a pace which will allow the plants to remain economically competitive with other rapidly advancing energy technologies.

One such innovation is accident tolerant fuels. ATF has shown potential to increase safety as well as increase fuel and system efficiency and performance.

The industry is making investments and moving forward. Southern Nuclear loaded two kinds of ATF cladding in our Hatch plant in February 2018. In 2019 three major fuel vendors in the ATF program plan to insert additional lead test assemblies in reactors operated by Southern Nuclear and Exelon Generating.

The results of this testing, and other tests being conducted by the Department of Energy, will provide fuel performance data and inform NRC fuel licensing. Testing and licensing activities will be conducted in parallel, which will help to accelerate the development timeline toward the goal of beginning batch loads of ATF fuel in commercial reactors by 2023 and full deployment by 2026. This timing is intended to support utility decisions regarding second license renewal.

The industry is appreciative of the NRC's plan to license fuel in an innovative way, while maintaining the highest levels of safety. Additionally, we are greatly benefiting from the DOE's National Lab's vast expertise and world class testing, modeling, and simulation capabilities.

We are grateful for the close attention and support Congress has provided to ATF and for its recognition that this program represents the cutting edge of innovation that will help preserve America's technological and strategic leadership.

I, like you, Senator Carper, like win-wins. The successful development of accident tolerant fuel has the potential to provide a win for everyone, safety, the environment, consumers, and plant operators by making light water reactors safer as well as more efficient and reliable.

In the process, if we develop a model for the transformation and modernization of the regulatory framework for nuclear plants, even better. For this to become a reality, we all—industry, regulators, the Department of Energy, and Congress—must continue to work together without delay.

Thank you.

[The prepared statement of Mr. Williams follows:]

John B. Williams
Nuclear Fuel & Analysis Director
Southern Nuclear Operating Company

John B. Williams is the Nuclear Fuel & Analysis Director for Southern Nuclear Operating Company. In this role, he is responsible for nuclear fuel, safety analysis, and risk-informed engineering for the Southern Nuclear fleet of generating plants. Additionally, John is the Corporate Functional Area Manager for the Fuel & Reactor Engineering functional area.

John joined Southern Nuclear as an engineer at the Southern Nuclear Corporate Headquarters in 2005. He has more than 20 years of experience in nuclear fuel, specifically reactor core design and licensing, dry storage of spent nuclear fuel, nuclear fuel procurement, and reactor engineering. Prior to joining Southern Nuclear, he was a nuclear engineer for the Tennessee Valley Authority.

John serves on the Department of Energy Industry Advisory Board for the Advanced Fuels Campaign and is the Utility Lead for the Nuclear Energy Institute ATF Working Group Safety Benefits Task Force.

John is a graduate of the Georgia Institute of Technology. He lives in Birmingham, AL with his wife, Carol.

STATEMENT OF JOHN WILLIAMS, SOUTHERN NUCLEAR OPERATING COMPANY
BEFORE THE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

ADVANCED NUCLEAR TECHNOLOGY: SAFETY AND ASSOCIATED BENEFITS OF LICENSING ACCIDENT TOLERANT FUEL FOR COMMERCIAL NUCLEAR REACTORS

September 13, 2018

INTRODUCTION

I am John Williams, Nuclear Fuel and Analysis Director at Southern Nuclear Operating Company. I am responsible for nuclear fuel, safety analysis, and risk-informed engineering for the Southern Nuclear fleet of generating plants, and am the Corporate Functional Area Manager for the Fuel & Reactor Engineering functional area. I am also a member of the Nuclear Energy Institute's Accident Tolerant Fuel Working Group, which is charged with guiding industry policy and action and is led by Mr. Danny Bost, Executive Vice President and Chief Nuclear Officer of Southern Nuclear.

SOUTHERN COMPANY

Southern Company is a natural gas and electric utility holding company headquartered in Atlanta, Georgia, with executive offices also located in Birmingham, Alabama. The nation's premier energy company, Southern Company provides clean, safe, reliable, affordable energy to 9 million gas and electric utility customers in 11 states. Southern Company is developing the full portfolio of energy resources, including carbon-free nuclear, advanced carbon capture technologies, natural gas, renewables, energy efficiency and storage technology, and creating new products and services for the benefit of customers.

Innovation is a central part of our strategy. We foster a culture that seeks to make transformational changes and understand that innovation and technology are engines of American greatness. We actively collaborate with the U.S. government, other utilities, universities and technology developers and remain at the forefront of technology development for the production, delivery and end-use of energy.

Southern Nuclear

Southern Nuclear, a subsidiary of Southern Company, currently operates six nuclear reactors: Units 1 and 2 at Plant Farley near Dothan, Alabama; Units 1 and 2 at Plant Hatch near Baxley, Georgia; and Units 1 and 2 at Plant Vogtle near Augusta, Georgia.[1] Together, Plants Farley, Hatch and Vogtle provide approximately 20% of the electricity used in Alabama and Georgia. This is made possible by our talented and committed workforce of more than 4,000 men and women working at our fleet of nuclear power plants and corporate

[1] Plant Farley is owned by Alabama Power Company. Plants Hatch and Vogtle are co-owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and Dalton Utilities.

offices, all of whom are also part of the larger Southern Company team of over 32,000 employees who are building the future of energy for the customers they serve. Southern Nuclear, as a subsidiary of the Southern Company, embodies the company's commitment to creating America's energy future and developing new products and services for the benefit of consumers through technological innovation. As such, we are proud to be taking a leadership role in the development and testing of Accident Tolerant Fuel (ATF).

It is an honor to appear before this Committee to share my views on the benefits of accident tolerant fuels and how we can overcome the development and licensing challenges before us. I thank Chairman Barrasso, Ranking Member Carper, and the Committee Members for taking the time today to discuss this pivotal technology that has the potential to make our Nation's nuclear fleet more reliable and efficient, as well as enhance its safety.

NEED FOR NUCLEAR INNOVATION, HOW ATF WILL ADVANCE NUCLEAR SAFETY (AND EFFICIENCY OF EVERYDAY OPERATIONS)

America's nuclear power plants run 24 hours a day, seven days a week, providing 20 percent of the nation's electricity and nearly 60 percent of its clean, emissions-free power. The nuclear fleet is a vital part of America's critical infrastructure, and an essential linchpin of a reliable, resilient national grid.

However, the sustainability of the US nuclear fleet will depend, in large part, on industry's ability to innovate at a pace which will allow the plants to remain economically competitive with other rapidly advancing energy technologies. I am proud to be leading a significant effort, currently, well underway, on one such innovation – Accident Tolerant Fuels – which has significant potential in this regard. The US Nuclear industry, in partnership with the Department of Energy (DOE), is developing highly advanced new fuels which offer improved performance under both accident and normal operating conditions. They have the potential to provide significant additional safety margin to protect the public and environment. The effort to develop ATF designs is accelerating as the value that these technologies bring becomes more apparent.

Early research and analysis work on advanced fuels has shown potential for the enhanced robustness and other properties of accident-tolerant fuels to (1) increase safety under [rare] accident conditions and (2) increase fuel and system efficiency, performance and therefore profitability under normal operating conditions.

The industry sees enough potential in the ATF program that we are pushing for an accelerated timeline for testing, analysis and licensing, with a goal for final deployment of ATF across the existing reactor fleet by the early- to mid-2020s.

The industry's rationale for an accelerated timeline is that utilities will be making second license renewal decisions by the early 2020s. Those decisions will be informed by whatever enhanced safety and economic benefits are evident from the results of the development program.

THE PATH FORWARD

Time is of the essence, and we are focused on accelerating the program by coordinating our activities across the fields of R&D, testing, modeling and simulation, licensing preparation, and safety and economic benefit analysis. Historically, development of new nuclear fuels can take upward of 20 years. Development on that timeline is not practical. The industry is working closely with the U.S. Department of Energy (DOE) and the U.S. Nuclear Regulatory Commission (NRC) to innovate on licensing and development, while maintaining the highest levels of safety. ATF presents an opportunity to showcase a transformative, risk-informed and streamlined regulatory and licensing framework.

FIRST LTAs LOADED AT HATCH

The industry is making investments and moving forward. We loaded two kinds of ATF cladding in Southern's Hatch plant in February—the first of many in-reactor tests to come across the nuclear industry. We will also be loading new fuel and cladding concepts at our Vogtle plant in early 2019. While the results from the Hatch test won't be available until the next refueling outage, we did learn from the experience about the regulatory framework that needs to be in place to ensure that future tests can take place in a timely manner.

FUTURE LTAs

Between now and 2022, the three major fuel vendors in the ATF program (General Electric/GNF; Westinghouse/General Atomics; and Framatome) will be inserting lead test assemblies comprising several concepts of advanced accident-tolerant fuel and cladding in U.S. commercial reactors operated by Southern and Exelon. The results of this testing (and of other tests being conducted in DOE research reactors and labs) will provide fuel performance data from commercial reactor environments and inform NRC licensing activities.

Some of these activities will be conducted in parallel, which will help to accelerate the deployment timeline toward the desired goal of beginning batch loads of ATF fuel in commercial reactors by 2023, and full deployment by 2026.

ATF FUNDING 2018-2019

We are grateful for the strong support demonstrated by both the Senate and House of Representatives for this program. The levels of funding are adequate to continue the development of the technologies in partnership with the DOE. We are grateful for the close attention and support that Congress has provided to ATF, and for its recognition that this program represents the cutting edge of innovation that will help preserve America's technological and strategic leadership.

NRC ATF LICENSING PLAN

The industry also is appreciative of the NRC's plans to license fuel in an innovative way which can accelerate the deployment of ATF in the marketplace. The NRC staff and Commission have been extremely diligent in coordinating their efforts with those of DOE and the industry to develop a

comprehensive and risk-informed licensing plan. The NRC's Transformation Initiative is also partly geared toward streamlining the regulatory framework for the timely and efficient licensing of innovative technologies such as ATF.

DOE ATF ACTIVITIES IN SUPPORT OF INDUSTRY

Our collaborative relationship and partnership with the DOE and National Labs cannot be understated. The National Lab testing, modeling and simulation, and coordination with the NRC on code development for licensing reviews, are essential aspects of the fuel development. We greatly benefit from the Labs' vast expertise and world class testing capabilities.

As an example of U.S. leadership, it is expected later this month that Idaho National Laboratory's unique TREAT facility will perform its first pulse test in more than 20 years, in an experiment to gather baseline data for ATF testing. The TREAT reactor is a national asset that was specifically designed to test and qualify nuclear fuels and determine their safety margins. It first opened in 1959 and was restarted last year after being shut down in 1994.

SAFETY AND ECONOMIC BENEFITS REPORT

Ultimately, the widespread use of these innovative technologies will depend upon the safety and economic benefits. The industry is keenly focused on understanding the range of potential benefits and is also evaluating how ATF can be an enabler to additional benefits from increased enrichment and fuel burnup. It is our intent to document the benefits in a report to be issued in the next several months. These efforts are closely coordinated with the Electric Power Research Institute, who is leading several of the analyses to ensure an independent perspective on the results.

CONCLUSION

The phase "win/win" has become a bit of a cliché, but the successful development of accident tolerant fuels has the potential to provide a win for everyone – safety, the environment, consumers, and plant operators – by making light water reactors even safer, as well as more efficient and reliable. If in the process, we develop a model for the transformation and modernization of the regulatory framework for nuclear plants, even better. However, for all of this to have meaning, we all – industry, regulators, Department of Energy and Congress, must continue to work together without delay.

Senate Committee on Environment and Public Works
Hearing entitled, *"Advanced Nuclear Technology: Safety and Associated Benefits of Licensing Accident Tolerant Fuels for Commercial Nuclear Reactors"*
September 13, 2018
Responses to Questions for the Record by Mr. Williams

Chairman Barrasso

1. Previous NRC licensing processes for nuclear fuel took more than 20 years to complete. What technological advances have been made that would shorten the time for NRC to license ATF?

   The most significant technological advances that could accelerate new fuel licensing are in the area of advanced modeling and simulation. The use of these tools can pinpoint areas where physical tests or experiments need to be conducted and improve the efficiency of data collection for the licensing process.

2. Your testimony described the regulatory process needed for Accident Tolerant Fuel (ATF) as "transformative." Do you think establishing a new process for licensing ATF could transform the way the NRC addresses other licensing challenges?

   While ATF licensing will not require a new regulatory framework, two focus areas for accelerated ATF licensing are increased reliance on modeling and simulation and conducting aspects of the licensing reviews in parallel. Both of these areas can contribute to addressing licensing challenges for advanced technologies.

3. What does "increased flexibility" as a feature of ATF mean to plant operators, and how can ATF flexibility help integrate nuclear power into a grid that has an increasing amount of intermittent power sources, like wind and solar?

   Intermittent power sources on the grid are challenging the status quo operation of nuclear units that have historically operated at near full capacity 24 hours a day, 7 days a week. Features of ATF can improve the ability of the nuclear units to respond to the need of grid operators to reduce or increase load quickly. Additionally, the margin provided by the fuel allows plant operators to be more flexible in their operation without challenging plant safety analyses.

Senator Markey:

4. Do you think it is a good idea to take the NRC out of the review process when testing new fuels?

   The NRC has always been, and will continue to be, a part of the testing, qualification and licensing of nuclear fuels through the use of NRC-approved Technical Specifications allowing for the insertion of lead test assemblies or through the approval of topical reports and license amendment requests for loading of new fuel designs.

5. If accident tolerant fuels are developed that improve plant safety, is there a risk that plant operators could feel that they can reduce safety margins in other areas, such as emergency preparedness?

   At this time, the industry is not pursuing any changes in emergency preparedness as a result of improved safety margins provided by accident tolerant fuels.

Senator BARRASSO. Thank you so much for your testimony, Mr. Williams.

Ms. Back.

STATEMENT OF CHRISTINA A. BACK, PH.D., VICE PRESIDENT, NUCLEAR TECHNOLOGIES AND MATERIALS, GENERAL ATOMICS

Ms. BACK. Senators Barrasso and Carper, thank you for your invitation to appear. I am pleased to discuss our perspective on NRC's approach to accident tolerant fuel licensing.

We believe the NRC must be prepared to license new fuels and claddings in the most timely way, while also ensuring that public safety is not undermined. To stop the premature shutdown of existing reactors, there is no time to waste.

In response to Fukushima, Congress appropriated funding for the ATF program to support the development of a new breed of nuclear fuels and claddings that provide enhanced safety margins.

In the 6 years since, significant progress has been achieved by three separate industry teams supported by the Department of Energy. The Westinghouse-General Atomics team is one of those. We are pursuing a highly innovative ATF technology offering markedly enhanced safety features and significantly improved economics for existing reactors.

It will do so by allowing operation at higher power and for longer periods of time, thus enabling fuel recycles that can last as long as 2 years, compared to the 18 months now possible. Higher efficiency and less maintenance down time mean a more economically competitive reactor.

Consequently, many utilities have been strongly supportive of the development and expeditious deployment of these new fuels. GA is developing the cladding material, made from a novel advanced silicon carbide ceramic composite. The material, named SiGA, was initially developed for our innovative Energy Multiplier Module, EM^2, an advanced high temperature, gas cooled, small modular reactor concept.

We believe the future of nuclear energy depends heavily on developing the new materials such as those that survive much higher temperatures and are much less chemically reactive. That is why we have invested significantly in SiGA material that safely can withstand temperatures of up to 1,800 degrees Celsius compared to metal claddings, such as Zircaloy, that start to fail around 800 degrees.

I am holding an example of a rodlet that will be inserted next year into the Advanced Test Reactor at the Idaho National Lab. It will undergo irradiations that will provide important data on the cladding performance in realistic reactor conditions.

Incredibly, we make this cladding starting from silicon carbide fiber. It is very flexible. The process we use creates a kind of rebar into our material, transforming it from a brittle ceramic into a fracture-tough material. Our results are very promising, and if they hold up, we will revolutionize the industry.

Ultimately, the same technology can be used in our EM^2 and other advanced reactors. Whether for ATF or advanced reactors, we must modernize our licensing processes before the reactors are lost.

I view the ATF licensing as a key step toward establishing good practices for advanced reactor licensing. Modernization means we will develop new and accelerated NRC processes without compromising the NRC's high safety standards. We must do this quickly.

For example, GA is developing a new methodology that we call Advance Fuel Qualification, AFQ. The idea, supported by DOE for funding, is to leverage computer modeling and simulation to reduce the amount of data needed for licensing.

Regardless of whether this methodology or another is implemented, early and sustained NRC involvement is key. I am pleased to see that the NRC draft project plan for the ATF recognizes that the past licensing path, which relies primarily on empirical data for fuel performance, cannot be the way of the future.

Good progress in licensing has been made for near-term technologies such as the metal coated claddings, but we also have to achieve the same progress for our long-term technologies, the more innovative technologies like ours that will require different assessments and regulations.

Since our SiGA cladding is a ceramic and not a metal, this revolutionary technology will be delayed until the NRC develops technical acceptance criteria for licensing approval. The good news is that the longer term technologies may be available only 2 to 3 years after the near term if the NRC moves promptly on them.

We welcome engagement with the NRC so that we can assist them fully in understanding these materials so they can develop their validation plan and license in the most timely and safe fashion.

We have been using technologies in the nuclear industry that is over 60 years old. It is time that we adopt new technologies, particularly those from materials sciences, not because it would be nice to have, but because they are needed for our industry's survival.

To be successful, the NRC, DOE, and industry must work closely together. If we do, we will find new ways to produce nuclear energy safely, cleanly, and at a much lower cost.

We hope this Committee will use its oversight and legislative powers to ensure that the NRC continues to design the new procedures it needs to license new technologies. Please visit San Diego. Seeing the fabrication in action will bring home to you the clear example of how ingenuity can transform the nuclear industry.

I thank you for your interest and support.

[The prepared statement of Ms. Back follows:]

Christina A. Back, Ph.D.
Vice President,
Nuclear Technologies and Materials
General Atomics

Dr. Christina Back has 28 years of experience leading research in private industry and U.S. Department of Energy (DOE) laboratories, including the DOE weapons complex. She is an internationally recognized expert in both fission and fusion energy research and regularly serves on committees for the National Academy of Sciences, National Nuclear Security Administration, and the DOE. She has over one hundred peer-reviewed publications, is a Fellow of the American Physical Society and is frequently invited to provide expertise for U.S. Congressional Committees and White House Science and Technology initiatives.

At General Atomics, Dr. Back is responsible for nuclear fission programs, which draw on a diverse portfolio of innovative technologies. Current activities focus on the development of advanced nuclear reactors for electric power, production of isotopes for medical uses, and fabrication of Accident Tolerant Fuel rods for safer nuclear reactors, among other projects.

Dr. Back earned her B.S. in physics from Yale University, and her Ph.D. in plasma physics from the University of Florida. She also spent two years as an experimentalist at the Ecole Polytechnique in France. Prior to joining General Atomics, Dr. Back spent 13 years performing research using high powered lasers at Lawrence Livermore National Laboratory in the Inertial Confinement Fusion and High Energy Density Science programs. She has devoted more than two decades to energy research and holds an active DOE-Q and US Department of Defense clearance.

Dr. Back has received numerous awards for her many noted contributions to the field, including the DOE Technical Excellence Award and Defense Nuclear Sciences Award. In 2013, she was named Woman of the Year in Business by the San Diego East County Chamber of Commerce.

Testimony of Christina Back, Ph.D.
V.P., Nuclear Technologies and Materials, General Atomics
Before the U.S. Senate Committee on Environment and Public Works
September 13, 2018

Chairman Barrasso and Ranking Member Carper, thank you for your invitation to appear before you today. I am pleased to discuss our perspective on NRC's approach to Accident Tolerant Fuel licensing issues.

We think it is extremely important that the NRC be prepared to license these innovative new fuels and claddings in the most timely way, while also ensuring that public safety is not undermined in the process of doing so. If we want to capture the benefits of these new technologies, and help stop the premature shutdown of existing reactors, there is literally no time to waste.

In response to the Fukushima accident of March 2011, Congress in FY12 appropriated funding for the Accident Tolerant Fuels (or ATF) program within the Department of Energy to support the development of a new breed of nuclear fuels and claddings. These were to be designed to offer significantly enhanced safety margins to avoid fuel meltdown in the low likelihood of a nuclear accident.

In the six years since then, significant progress has been achieved in the design, engineering and initial testing of several ATF concepts being developed by three separate industry teams supported by DOE. The Westinghouse-General Atomics team is one of those.

The Westinghouse-General Atomics team is pursuing a highly innovative and promising ATF technology. Not only is it designed to offer markedly enhanced safety features, it also should significantly improve the overall economics of operating the existing fleet of nuclear reactors. It will do so by creating the capability to operate at higher power and for longer periods of time, thus increasing fuel utilization, reducing waste, and making possible refueling cycles of as long as 2 years, compared to the 18 months now possible. Higher efficiency, and less maintenance down-time, mean a more economically competitive reactor.

With the financial challenges that have led to the premature shutdown of several reactors, such enhanced performance could significantly improve the economic competitiveness of the current fleet. Consequently, many utilities have been

strongly supportive of the development and expeditious deployment of these advanced accident tolerant fuels.

At General Atomics we are developing the cladding material, made from a novel form of an advanced ceramic composite of silicon carbide, that will house the Westinghouse uranium-based fuel pellets.

GA has been investing in the development of this advanced silicon carbide composite material since well before the Fukushima accident. This material, which we call SiGA^{TM}, was initially developed for our innovative Energy Multiplier Module, EM^2, an advanced high temperature gas-cooled fast small modular reactor concept.

We believe the future of nuclear energy depends heavily on developing the new materials that will survive much higher temperatures, and be much less chemically reactive than those we have today. That's why we've invested significantly in silicon carbide composites that safely can withstand temperatures of 1800 degrees Celsius compared to metal claddings, such as the current zircaloy, that start to fail around 800 degrees.

I am holding an example of the rodlet that will be inserted into the Advanced Test Reactor (ATR) at the Idaho National Lab in March of next year, 6 months from now. It will undergo an irradiation test that will provide valuable data on the cladding performance in realistic reactor conditions.

Incredibly, we make our cladding tubes starting from silicon carbide thread. This process creates a kind of rebar into our material, transforming it from a brittle ceramic into an extremely fracture-tough material. Our results have been promising so far. If they hold up, we could truly revolutionize this industry.

Ultimately, the same technology can be used in advanced reactors, such as gas-cooled, or molten salt reactors. For instance, at GA, a slightly different cladding configuration would be used with uranium carbide fuel to be the fuel rod in EM^2. And molten salt reactors need materials, such as our SiGA^{TM} ceramic composite, that will not corrode as most metals do.

Whether accident tolerant fuel, or advanced reactors, we must modernize our licensing processes before more reactors are shut down. I view the ATF licensing as a key first step toward licensing new technology advanced reactors. We must look to new and accelerated NRC activities and processes to license highly

innovative fuels, and the advanced materials, **without compromising the NRC's high safety standards. And we must do this quickly.**

For example, GA is developing a new methodology that we call Accelerated Fuel Qualification, or AFQ™ for short, which we hope will help accelerate the licensing of advanced fuels. The idea is to leverage computer modeling and simulation to reduce the amount of data needed for licensing.

Regardless of whether this methodology, or any other existing licensing path is implemented, early and sustained NRC involvement is key. Since I last appeared before this committee, I am pleased to see the recent NRC draft Project Plan for ATF. It recognizes that the past licensing path, which relies primarily on empirical data of fuel rod performance, cannot be the way of the future.

Good progress on licensing has been made for "near-term" technologies, such as coated metal claddings. But, we also have to achieve the same progress for what are called the "longer-term" technologies: these are the more innovative technologies that will require different assessments and risk-informed, performance-based regulations.

For example, a great benefit of the silicon carbide composite is the fact that it will withstand temperatures more than twice as high as those of today's metal claddings. Those claddings will fail at those higher temperatures, even if the metal is coated with materials that reduce hydrogen generation.

But our silicon carbide cladding is a ceramic, not a metal, so this revolutionary technology will be delayed until the NRC develops technical acceptance criteria. Given the premature shutdowns of existing LWRs, there simply is no time to waste. The good news is that these "longer-term" technologies may be available only 2-3 years after the "near-term" ones if the NRC moves promptly on them.

We welcome engagement with the NRC so we can assist them in fully understanding these materials quickly enough so they can develop their own validation plan for the modeling, and the data they will need, to license them in the most timely and safe fashion.

We have been using technologies in the nuclear industry that are, in many cases, in excess of 60 years old. It is time we adopt new technologies, particularly from the materials sciences, not because they would be nice to have, but because they are needed for our industry's survival. It is particularly important for the NRC and the

DOE to work closely together to introduce these new technologies into the marketplace. American industry also stands ready to cooperate with them. If we do this, we will find new ways to produce nuclear energy safely, cleanly and at much lower cost.

We hope this Committee will use its oversight and legislative powers to ensure that the NRC can, and will, continue to design the new procedures it needs to facilitate the introduction of the new technologies required to support an ever more robust nuclear power industry.

Please find the time to visit us in San Diego, I would be honored to give you a tour of our lab facilities. Seeing the actual fabrication in action will bring home to you a clear example of how ingenuity can transform the nuclear industry.

Thank you for your interest and support. I would be happy to answer any questions.

Senate Committee on Environment and Public Works
Hearing entitled, *"Advanced Nuclear Technology: Safety and Associated Benefits of Licensing Accident Tolerant Fuels for Commercial Nuclear Reactors"*
September 13, 2018
Questions for the Record for Dr. Back

Chairman Barrasso:

1. The long-term development of General Atomics' nuclear fuel requires more modeling and simulation than near-term accident tolerant fuel designs. This is necessary to learn how the new material will react in a nuclear power plant. DOE's world-class modeling expertise will be critical to provide accurate data for NRC to use in the licensing process.

   What are the challenges and opportunities for NRC and DOE to collaborate on modeling and simulation?

   Response:

   GA's SiGA™ ceramic nuclear fuel cladding provides an important opportunity to advance the U.S. nuclear energy program by combining our high-fidelity modeling capability and high-speed computing with our advanced experimental capabilities.

   The goal is to reduce the time and cost of introducing exciting and essential new technologies into our aging nuclear programs, while maintaining or even improving safety.

   Currently, the NRC requires extensive empirical data to validate the safe performance of new materials. This effort entails lengthy, in-reactor irradiation experiments to collect data on thermal, chemical, and radiation effects on the material in a reactor environment. For example, the process to make a relatively modest change from one metal alloy to another, Zircaloy to ZIRLO, took over 10 years.

   In terms of cost, a single irradiation experiment to collect data for licensing can cost $1-5 Million. The total for licensing can easily reach over $100 Million when multiple experiments, in addition to the supporting personnel and facility infrastructure, are taken into account.

   Opportunity: Reduce licensing cost and schedule through the government's investment in high-fidelity modeling programs to simulate the performance of new materials in fuel rods and other core components. Programs such as DOE's NEAMS and high-speed computing, in particular the peta-scale and the new exa-scale systems, can simulate current light water reactor material interactions down to atomistic levels with much greater speed. Indeed, fuel performance codes can simulate 5-year long irradiation experiments, spanning the entire lifetime of a fuel rod, in just a few days of computer simulation.

Challenge: Validate simulations with experimental data to ensure they have sufficient fidelity to predict fuel performance for licensing purposes. To reduce the cost and time of licensing we **must** take more advantage of simulations. Both the models and the computational algorithms in the simulations of fuel performance must be benchmarked with experimental data.

Under the current methodology, it will likely take 15 to 20 years to experimentally demonstrate that improved materials are safe under reactor operating conditions. To achieve more efficient licensing, DOE should support an integrated program of simulation and experiments that verifies the underlying physics models affecting fuel performance. In parallel, the NRC needs to establish standards to incorporate modeling; essentially, they need to determine acceptance criteria for the "data" generated by simulations that are equivalent to data obtained through experiments.

In short, a methodology to demonstrate that new materials perform within acceptable bounds can, and must, be developed. With reliable simulations of fuel performance in reactors, the in-reactor experimental testing burden **can be reduced without sacrificing safety.**

GA has taken an important step in this regard. We have teamed with the Oak Ridge National Laboratory and the University of Tennessee to develop the Accelerated Fuel Qualification (AFQ^{TM}) methodology, which extrapolates the results of short-term micro-irradiations to full-scale component performance by high-fidelity modeling. This work is sponsored by DOE-NE under the U.S. Industry Opportunities for Advanced Nuclear Technology Development program. Under this program, the team will demonstrate the effectiveness of AFQ for the SiGA-clad fuel employed by GA's EM^2 advanced reactor.

Under this same program, DOE-NE has also funded an effort to engage the NRC to review the application of the AFQ methodology to substantially reduce long experimental fuel qualification times. The NRC has expressed enthusiasm for engaging in this program and has invited GA and the DOE to participate in the review of their in-house fuel performance computer simulation capabilities. GA views this collaboration as a significant step for our country to once again lead the world in the peaceful application of nuclear energy.

To execute this vision, we need stable, well-funded, cost-share technology development and de-risking programs. **This Committee's oversight of these efforts will be essential to ensure this happens.**

We think that funding efforts totaling about $30 Million in FY19 for modeling could be raised to about $70 Million by FY21 specially since CASL funding of about $30 Million is slated to end after FY19. Also, we suggest that the future modeling program solicitations be modified to include funding (perhaps an additional $25 Million, for a total of about $95 Million) for the experimental program required to validate the modeling. The desired result would be programs that would strongly couple the modeling to the experiments, which is what ultimately is required for success.

We also need to attract the talented young scientists and programmers who can make this happen. Today, many of our most talented, young professionals do not see nuclear energy as an exciting career opportunity. This, we can and must change.

Senator Duckworth:

Illinois gets a significant amount of its energy from nuclear sources. Illinois' 11 reactors — the most of any state — generate half of the state's electricity.

These facilities are major job creators in my state and an important source of carbon-free energy. That is why I am deeply invested in ensuring that our existing nuclear fleet has the policies they need to thrive.

2. What are your thoughts regarding accident tolerant fuels and their ability to help our existing reactors maintain operations?

Response:

The short answer is that ATF can help improve the economics and safety of operating existing reactors, and thus help keep them in service longer than otherwise. Therefore, it is important that DOE fund all of the ATF programs, including the nearer-term as well as the longer-term more advanced options.

The NRC categorized accident tolerant fuels (ATF) into two groups: near-term and long-term. The long-term group includes cladding, the fuel rod housing, that is made from ceramic silicon carbide material developed by GA called SiGA™. This material offers significant benefits over current, and near-term, cladding because it does not melt and is one of the hardest materials on earth.

SiGA retains nearly full-strength and its overall geometrical shape at temperatures above 1800 degrees Celsius. By contrast, Zircaloy, the current metal cladding, significantly softens at 800 degrees Celsius and then balloons and fails. It has been predicted that SiGA would have survived the Three Mile Island accident and allowed the reactor to be recoverable. It also is expected to be able to survive most severe accident scenarios where near-term accident tolerant fuel solutions would fail.

Under accident conditions such as those at Fukushima-Daiichi, SiGA is superior because its reaction rate with water is a thousand times slower than Zircaloy. The near-term ATF claddings consist of Zircaloy with a thin metal coating, such as chromium, intended to retard the highly energetic reaction of Zircaloy with water that produced the hydrogen. Although the coating helps, it can be compromised or delaminate and does not substantially change the fundamental chemical or physical behavior of Zircaloy that we

saw at Fukushima. However, because coated Zircaloy may be available sooner than SIGA ATF, it merits continued support.

While the properties of silicon carbide have been known for decades, the challenge has been in making it into various useful shapes. GA's contributions include the technologies to make basic shapes such as plates and cylinders and to join them by a radiation resistant process. While this sounds simple, it is incredibly complex and is a major step forward in materials science.

In addition, SiGA-based ATF can improve the economic performance of existing reactors in several ways. For one, it has superior nuclear properties over Zircaloy because it enables the reactor to use less fuel for the same power output. It can also enable the fuel to burn for a longer period of time, thus reducing the frequency of plant outages for refueling resulting in a greater number of operating days and thus more revenue. The fuel also has much larger safety margins, which could support a plant power uprate and could lessen the burden of some of the more expensive safety precautions.

3. What are the main obstacles to deployment of accident tolerant fuels?

Response:

Both DOE-NE and the NRC understand the importance of ATF for supporting the current fleet as well as for commercializing advanced reactors. Nevertheless, there are several obstacles that could impede progress toward implanting ATF. These include:

1) *Lack of availability of irradiation facilities for testing advanced ATF prototypes.* The only facility for testing integral fuel performance of ATF in the U.S. is the Advanced Test Reactor (ATR) at the Idaho National Laboratory (INL). This facility is over 60 years old and requires frequent maintenance, including a planned shutdown after the end of 2019. It is also principally used for testing naval reactor fuel, with lower priority space for commercial fuel testing. There used to be one other option available, the Halden Reactor in Norway, but this facility was recently closed by the Norwegian government. Thus, lack of irradiation test facilities in the U.S. is a serious impediment not only to ATF but to the future U.S. nuclear program in general.
2) *Insufficient support for a high-fidelity modeling effort that is benchmarked by experiments.* As explained in the response to Chairman Barrasso's question, high-fidelity modeling and high-speed computation have reached the point where computer simulations can supplant the need for extensive irradiation testing in reactors such as the ATR. As an example, GA's Accelerated Fuel Qualification (AFQ^{TM}) program, supported by DOE-NE, seeks to extrapolate the results of micro-irradiations to full-scale components by high-fidelity modeling in order to expedite fuel qualification and subsequent NRC licensing without compromising safety. These micro-irradiations can be done in smaller reactors like the High Flux Isotope Reactor (HFIR) at Oak

Ridge National Laboratory. Although the funding is for a two-year exploratory program, we believe that an expanded program involving more participants, such as the materials group at Los Alamos National Laboratory and the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program, can lead to expeditious and successful application of AFQ to aid in licensing.

The current NEAMS funding is now approximately $30M, but $70M could be productively spent, especially since CASL funding will be ending after FY19. A special emphasis on new materials, not just neutronics, would accelerate adoption of innovative fuels. In addition, associated support for experimental benchmarking linked to simulations could be prioritized in future DOE awards. The NRC also could help more if its funding for these activities were increased by about $10 Million.

Senator BARRASSO. Thank you for your testimony. There is an open invitation now to San Diego. Thank you.

I appreciate the testimony from everyone.

Mr. Furstenau, let me start with you.

Hurricane Florence is rapidly approaching the southeastern United States. One of the news stories today showed a map of North Carolina where the nuclear power plants were by the coast.

Will you update us now on how the NRC nuclear power plants and other NRC licensed facilities are preparing for the hurricane?

Mr. FURSTENAU. Thank you for the question, Senator Barrasso.

Based on available information, the impacts from the storm surge, winds, and flooding at Brunswick and other plants in Florence's path will fall well below the plant design parameters. One reactor at Brunswick has started shutting down. Both Brunswick reactors are expected to be fully shut down hours before hurricane force winds could affect the site.

All U.S. nuclear power plants have the additional resources like pumps, generators, and procedures required by the NRC after the Fukushima accident to maintain key safety functions during any severe event like this. Available information indicates that the plants can remain safe during the storm without the post-Fukushima equipment.

NRC inspectors are at every U.S. operating power plant, following normal agency procedures. Additional inspectors have been dispatched to the plants in the storm's path. The NRC will continue to observe the plants' response in the storm and its aftermath.

Senator BARRASSO. We appreciate that update. Thank you. It is very reassuring.

Moving to the topic of discussion today, last year the Nuclear Regulatory Commission established an Accident Tolerant Fuel Steering Committee. The steering committee just issued the first version of a project plan for the licensing of the accident tolerant fuels.

The plan serves as the strategic document for NRC and the private sector to make accident tolerant fuels commercially available. The plan includes multiple benchmarks and goals for timely action by the NRC staff.

Do you believe the NRC can adhere to the scheduled outline in the steering committee's plan, and will you commit to notifying the Committee if the NRC is unlikely to achieve its benchmarks?

Mr. FURSTENAU. Mr. Chairman, the NRC is committed to that plan, and we do believe we can meet the milestones in that plan. Of course, it is a living document, and I think the other panel members would agree that if there are things that come up during the progress on the plan that need to be changed, we would do that with full and open participation of the stakeholders.

Senator BARRASSO. Thank you.

Ms. Taylor, the Electric Power Research Institute is uniquely positioned as an independent, non-profit organization, to collaborate on accident tolerant fuel research. We appreciate that.

Can you explain how your organization's independence can give policymakers and the public greater confidence about the research

the NRC, the Department of Energy, and commercial fuel vendors are conducting on accident tolerant fuels?

Ms. TAYLOR. Yes. An example of that would be the work we have done initially to assess the potential ATF concepts where we have used modeling capabilities we have to model how those fuels would perform during normal operation and during accident scenarios.

That provides a base of information that is non-biased that people can use for decisionmaking.

Senator BARRASSO. Thank you.

Mr. Williams, can you explain how the economic benefits of accident tolerant fuels could encourage utilities to renew licenses for existing nuclear reactors?

Mr. WILLIAMS. Yes, sir. As utilities reach the end of their operating license, they are beginning to evaluate whether or not to make the significant investment of whether or not we will renew our operating license.

There are a number of factors involved. One is the cost of the energy that we will bring to the market and the available market for that. If ATF is able to provide the economic benefits it shows, then it makes our plants more effective and improves the business case by which we would make those decisions.

Senator BARRASSO. Dr. Back, General Atomics is developing a particularly innovative accident tolerant fuel. I understand the new fuel would be suitable for today's commercial light water reactors as well as tomorrow's advanced reactors.

Will you describe how this fuel differs from accident tolerant fuels that other commercial vendors are currently developing?

Ms. BACK. Thank you.

The material we are working with is actually something you could not have made 20 years ago. This is a ceramic, like your coffee mug, which is very good at retaining the fuel. In this particular case, because we have the fibers inside, it acts like rebar cement. That is what we call fracture-tough.

Very important in these future scenarios to give added safety margins is it goes up to very high temperatures. In fact, this material does not melt. That is why the temperature difference is so vast between metals and ceramics.

Also, it retains re-coolable geometry. This fuel, in an accident, would not breach in the same way that a metal would. Different metals have different behaviors than ceramics. These materials can increase the performance.

Senator BARRASSO. Let me follow up with that, if I can, the difference between near-term and long-term. How is the NRC's project plan addressing both, the near-term use of accident tolerant fuels as well as longer term proposals like those that General Atomics is developing?

Ms. BACK. The plan has been very nice because it lays out by category, for instance, thermal hydraulics, burn up, and so on. The key difference, I think, is that for many of the near-term concepts, Zircaloy is still the metal cladding that is providing most of the function. There is a coating on top to, for instance, decrease the hydrogen generation.

Fundamentally, that does not change the properties of the cladding to allow it to have a higher margin in safety. The fact is that

we go up to much higher temperatures, can have a coolable geometry, have orders of magnitude less in hydrogen generation, and the corrosion is much different. In Fukushima, there was an exothermic reaction, which is what caused the hydrogen production. That would not happen with this material.

Those are the kinds of things that now require different fuel performance calculations because the material is fundamentally different. Those calculations have to be included in the regulations and taken into account. The full benefits will actually be seen there.

Some of the early calculations now do not fully take into account some of these benefits. That is why there is a second generation of the EPRI report that will be coming up. I think those things will be reflected much better as we are able to incorporate these into the fuel performance calculations.

Senator BARRASSO. Thank you so very much, all of you.

Senator Carper.

Senator CARPER. When my sister and I were little kids growing up in Danville, Virginia, sometimes our family listened to the news on ABC radio, a guy named Paul Harvey. We were just little kids. When he finished the first part of his news, he would say, page 2 and go on to the rest of the news, and finally, page 3.

I want to ask you about page 2. There have to be some smart folks around this country who are looking at this technology, accident tolerant fuels, and also what Christina talked about over at her company, and they are saying that makes no sense, that is not very smart, that is not a good investment of taxpayer dollars. Why would we do that?

I want to ask one or more of you to explain those arguments against going down this path and then rebut them. Lay out briefly the arguments against this technology and rebut them, one or more of you, please. I do not care who goes first.

Ms. TAYLOR. I don't know that I can fully address that question. However, one concern certainly is the ability to develop and license these quickly enough to make a difference in the existing reactor lifetime plants are currently licensed to. There is concern that can these be licensed quickly enough?

Senator CARPER. Others, please?

Mr. Williams.

Mr. WILLIAMS. Another concern is that it is going to increase the cost of the fuel that we purchase for our plants as we deploy new technologies. That is why the safety, and therefore the economic benefits analysis, are important as we try to make the business case that this is in the best interest of our customers and results in an overall lower cost.

Senator CARPER. Thanks.

Ms. Back.

Ms. BACK. I would like to point out that we are in a new world where materials are understood better. We can make parallel improvements, and calculations can be taken into account to really leverage the amount of data to help us understand the behavior of the fuel.

The concern is that it will take too long to incorporate these new materials. Really, the rebuttal is that if we do not do this, we will not be able to make cost competitive nuclear energy.

We will not be able to take advantage of new engineering and science that has happened that, for instance, changes your phone from something that used to be a rotary dial that is now in everybody's pocket, which is really a little computer.

There are advantages in new technologies that are worth waiting for and worth investing in. In this case, because we can do parallel advances in the modeling, licensing, and technology, all of these can come together if we work well together.

Senator CARPER. Thank you.

Second, I want to address work force.

I will start with you, Mr. Furstenau.

The NRC will recruit the talent it needs to keep up with the new nuclear technology. What more could or should Congress do to help overcome any skill gaps you are aware of?

Mr. FURSTENAU. Thank you for your question, Senator Carper.

I think the work force planning is very important; how are we going to be ready for this in the future? I agree.

At the NRC, we have been doing strategic work force planning exercises to adapt to that with an aging work force in our own agency and the outlook ahead for what may be coming down the line with accident tolerant fuel or other advanced reactor concepts. We need to recruit that talent.

We are doing, like I said, strategic work force planning exercises. There is the Integrated University Program that NNSA, DOE, NRC, and Duke do complementary work on. Those types of activities are important to grow that work force in the future.

Senator CARPER. Thank you, sir.

Dr. Back, as someone who works for a company that is a client of the NRC, do you feel the agency has the necessary work force to review the new technologies that you described to us today or does more need to be done?

Ms. BACK. I think it is a challenge, because the new material and new technologies require new learning, but there is a very eager and young group of engineers, nuclear engineers, and scientists that really do want to make a difference to clean energy.

I think the work force is eager to try and engage and put together a licensing plan as well as develop the technology. The skills that are needed I think can be found as long as we work together to understand the material and to show the data. The NRC has to make their independent judgment of the data.

We need to put together plans that take into account these different behaviors. I think those are challenging questions that the younger generation is eager to adopt and get involved with. I think there will be people who can fill those skill gaps.

Senator CARPER. When I come back, I would like to ask some questions about Halden, the test reactor and how the U.S. Government is going to fill the gap when Halden is no longer an option. Thank you.

Senator BARRASSO. Senator Whitehouse.

Senator WHITEHOUSE. Thank you, Chairman.

Welcome, all of you, and thank you for being here.

I am very interested in the prospect of advanced reactor concepts that hold the promise of being able to repurpose spent nuclear fuel. At present, we really do not have a plan for the spent nuclear fuel stockpiles.

There are technologies emerging that would appear to be able to—and are, in some cases, asserted to be able to repurpose that stockpile and make some positive use of it. For instance, General Atomics has a design for an energy multiplier module that explores this potential.

I am wondering if I could get your comments on how far we are in that direction and whether there are some early positive indicators about nuclear technologies that could repurpose existing nuclear waste stockpiles.

Why don't we go right across?

Ms. BACK. Thank you for the question.

The EM[2] Energy Multiplier Module is actually designed so that it can burn light water waste as well as its own waste. We really do not look at it as waste; we look at it as spent nuclear fuel.

In the case of light water reactors, 95 percent of the material that is in the fuel rod is actually Uranium 238, which cannot burn. That is why you need an advanced reactor, in this case a fast reactor, so that you can burn that material.

In that case, you can take a light water reactor core, do a process to remove the fission products, and then reform that fuel, and in a sense, recycle it. It is done with a process which is not the conventional reprocessing. It is a dry process.

That process has been demonstrated. Canada and Korea have different aspects of it that have been successful. I think this can be incorporated so that we generate new fuel cores for EM[1] or some advanced reactor. It burns over its period of time, recycles, and over some 200 years, you can get rid of all of the geological waste that would be in the light water reactor spent fuel rod.

Senator WHITEHOUSE. Mr. Williams, do you have anything to add?

Mr. WILLIAMS. At Southern Nuclear, we are obviously paying attention to the advanced reactor technologies and staying abreast of the claims of those. At this time, we have not pursued any action there.

Senator WHITEHOUSE. Ms. Taylor.

Ms. TAYLOR. I cannot speak to any specific design, but I will say that in the advanced reactor space, similar to the accident tolerant fuel space, many companies are innovating with different approaches. It is an area where we see a lot of early career people contributing as well.

Senator WHITEHOUSE. Mr. Furstenau.

Mr. FURSTENAU. The NRC is open to review new and innovative designs as vendors prepare for that.

Senator WHITEHOUSE. In the Committee, we have cleared the Nuclear Innovation and Modernization Act, which is now running hotlines for passage on the Senate floor. Senators Barrasso, Inhofe, Crapo, Booker, and myself are the original co-sponsors.

Senator Crapo and I also have the Nuclear Energy Innovation Capabilities Act, which has passed the Senate by unanimous voice vote.

The first bill would reform the NRC licensing process to open it up to more technologies than the light water reactors. The second would help facilitate collaboration between the private sector and our National Labs toward the development of these technologies.

We also just passed in the Senate a third bill that I did with Senators Crapo and Alexander that would allow and fund the Department of Energy to use spent Navy fuel for research in these advanced nuclear reactor technologies.

Do you see those three measures as positive steps in freeing up the regulatory authority and the research capability to move forward in this space of potential reactors that could use our existing nuclear spent fuel stockpile as fuel, recycle, or reuse it?

Start the other way with Mr. Furstenau first, and we will go across.

Mr. FURSTENAU. Senator Whitehouse, I really cannot comment on pending legislation from an NRC standpoint.

Senator WHITEHOUSE. Fair enough.

Ms. TAYLOR. We are seeing some very positive results with the innovative companies working together with the National Lab capabilities to move a lot of technologies forward.

Senator WHITEHOUSE. I think actually we are seeing kind of a signal response thing. The National Labs have stepped forward more. Seeing this legislation going forward and seeing its support, they are actually a bit ahead of the actual bill, which is a good thing. It is a good signal response.

Mr. WILLIAMS. Yes, sir, absolutely. Southern Nuclear believes that any legislation that promotes innovation in nuclear is a positive thing and will benefit the industry overall.

Ms. BACK. I absolutely think it helps because by nature, nuclear energy needs to be conservative because we need to be safe, and we want to keep the gold standard of the NRC.

That means that we have to change the regulations and the ways we assess materials and develop the processes to meet the need of bringing in new technologies. That means looking at how we characterize the materials, developing new regulations, which are not now based on a deterministic measurement over 30 years of data.

We have power in the computing codes that has been brought to every other area. For instance, in developing your cars and planes, all of those use modeling and simulations. This is something where I think the regulations need to be accelerated and changed. I think the legislation helps encourage cooperation among the National Labs, the utilities, NRC, and all of us. All of that is absolutely necessary for it to go forward.

Senator WHITEHOUSE. Thank you, Chairman. Again, thank you for your support on these pieces of legislation.

Senator BARRASSO. Thank you for your leadership as well. It has been a good, cooperative effort.

Senator Carper, we were talking about what happened with the Halden test reactor. I am going to ask a couple questions, and I know you have a couple as well. I am going to start with Ms. Taylor.

In June the organization overseeing the Halden test reactor in Norway announced it would permanently close the reactor. The re-

actor would have provided critical scientific data necessary for licensing of accident tolerant fuels.

In July the Electric Power Research Institute participated in a Department of Energy workshop at the Idaho National Lab. The workshop assessed how to fill the gaps in testing capacity that closure of the Halden reactor has left behind.

Could you talk about what the primary gaps in testing capacity were that were identified, and what can we do to fill the gaps?

Ms. TAYLOR. I can address that to some extent.

The Halden test reactor project is more than just a facility. It is a facility that had been a multinational collaboration to fund and plan testing. The reactor had some unique capabilities, two of which were the ability to test the large number of specimens in parallel, so it was very large for a test reactor. It also had some looped capabilities.

Many of the stakeholders have come together. You mentioned the July workshop. Idaho National Lab was the place to kind of convene what the need was. A game plan has been laid out to provide many of those capabilities through additional capabilities at Idaho.

Senator BARRASSO. Are there policies perhaps that the Department of Energy, the Nuclear Regulatory Commission, or even Congress should consider to try to fill some of these testing gaps, or do you think we will be OK as we are heading?

Ms. TAYLOR. I cannot really address the policy issues.

Senator BARRASSO. OK.

Mr. Furstenau, what steps is the NRC taking to ensure that the Halden closure does not really slow the progress on licensing the accidental tolerant fuels?

Mr. FURSTENAU. At the NRC, we also participated in the workshops at the Idaho National Lab. At this point, we think there is no significant impact on the current test plans as we know. I am confident that the Department of Energy, the capabilities at the DOE sites, and possibly the universities will really fill that gap in the longer term.

Senator BARRASSO. By history, before joining the NRC in your current position, you spent years at the Department of Energy, so you have a pretty good understanding of what the capacities are. You feel they are going to be able to fill this?

Mr. FURSTENAU. Yes, sir.

Senator BARASSO. OK. Thank you.

Senator Carper, do you have additional questions?

Senator CARPER. I do have a few. Thanks, Mr. Chairman.

Again, thanks very much for being with us today.

Mr. Williams, 10 or so years ago, we were talking about at least 25 brand new light water reactors being built in this country. Do you remember that? I do.

Mr. WILLIAMS. Yes.

Senator CARPER. All were expected to come online maybe this year or soon thereafter. In reality, our Nation is only building now, as we know, two new light water reactors. Those two are being built in Georgia by your company.

The effect of the Westinghouse bankruptcy on the nuclear industry is troubling for us, and I am sure for you and others. Can you take a moment and tell us how are things going at Vogtle and what

are some of the lessons learned that might help the next generation of nuclear power?

Mr. WILLIAMS. Senator, I appreciate your question.

Unfortunately, in my role, I focus on our operating fleet of reactors and am not aware of all of the issues associated with the project. We would be happy to respond to your question in writing.

Senator CARPER. Does anyone have any insights briefly in this regard? I think it is a pretty good question, better than most of my questions. Does anyone else have any insight you would like to share?

[All respond in the negative.]

Senator CARPER. A response for the record from Mr. Williams, but others would be welcomed.

Mr. Furstenau, with respect to NRC planning for accident tolerant fuels, the NRC's draft plan on accident tolerant fuels states, I believe, that the agency will use applicant provided data or DOE data to determine the safety of a concept and that the agency will not perform its own independent testing.

Would you elaborate on this point? Does the NRC do this in other circumstances? Why does it now make sense to do it for accident tolerant fuels?

Mr. FURSTENAU. Senator, you are correct about the project, the current plan does not. The assumption is being made that we will not do our own confirmatory testing. However, in the testing programs that are developed by the vendors and industry, we will use data that comes out of that testing program and independently look at that and review it from a confirmatory analysis standpoint.

However, at this point in time, we do not see a need for additional confirmatory testing on these near-term concepts.

Senator CARPER. Thank you.

Dr. Back, back to you. As I mentioned in my statement, extreme weather events are expected to be more frequent and more extreme due to climate change. Already nuclear power has proven to be quite resilient in this country during these extreme weather events. We are going to be closely watching and be in close step with the NRC to make sure that is the case during Florence.

Would you like to take a moment and discuss how the technologies your company is developing will allow nuclear power to be even more resilient and safe during extreme weather events like Florence and those that follow?

Ms. BACK. Yes. Thank you.

As you know, nuclear power performed very well during the Harvey event. There are already advantages in nuclear energy, for instance, of having all the fuel onsite. You do not have pipelines or electricity lines.

For the advanced reactor, there has been a lot of thought along making them more resilient. One, in particular, is the EM^2 that we envision is a smaller, more compact reactor. Importantly, it is underground so there is protection from things like Florence.

There are passively safe systems and built in redundancies that are consistent with what are typical NRC regulations so that we make sure it is safe in case of loss of power. For instance, there is an important way that the power conversion unit works with

cooling and kicks in with natural convection, if that does not pan out, if there is total loss of electricity.

All of those aspects are thought through and incorporated into the reactor as well as the other efficiencies to be able to run the fuel at higher utilization so that you actually do not need to access the core for 30 years.

Senator CARPER. Thank you. I have one more.

This is kind of a wrap up question. I am going to ask each of you on the panel to respond to this question if you would.

Mr. Furstenau, if you would go first.

If you had one piece of parting advice to give to us on the Environment and Public Works Committee with respect to advanced nuclear fuels, what would be that advice?

Mr. FURSTENAU. I think, in my opinion, it would be we all need to be open and adaptive to enabling new technologies like ATF and advanced reactor concepts that have the potential to make nuclear power even safer.

Senator CARPER. Thank you.

Ms. Taylor.

Ms. TAYLOR. I agree. Continuing to encourage innovation in this space which has not always been innovative is yielding new options.

Senator CARPER. How should we express that encouragement?

Ms. TAYLOR. I do not have any suggestions.

Senator CARPER. Really? All right.

Mr. Williams.

Mr. WILLIAMS. I think the way to encourage it is to encourage the collaboration between industry and public-private partnerships working together. This is a great example of collaboration between the Department of Energy, the fuel vendors, the utilities, and the Electric Power Research Institute to rapidly advance an innovation to deployment.

Senator CARPER. Thank you.

Dr. Back.

Ms. BACK. My overriding concern is that we need to have data, and that means irradiations, something like the advanced test reactor at Idaho National Lab and as you were asking about in Halden.

Those are expensive and need to be done well and be instrumented so that we get the maximum amount of data so we can push forward and make sure we have all the information needed to make sure these materials are safe and perform as they behave.

We need a prioritization and maybe another look at what we can do to make more opportunities available for irradiation testing.

Senator CARPER. Let me ask, very briefly, would the other panelists respond to what Dr. Back just said?

Mr. FURSTENAU. I think her point on needing irradiation test data when you then use modeling and simulation codes, you need to have data to verify those models and codes. I think especially for the concepts like General Atomics referred to, you do need some of that material that has not been used before. You need that test data to help validate it. It also helps with the licensing process as well as the safety case for the licensees.

Senator CARPER. Any other comment in response to what she said?

Ms. TAYLOR. Just to understand how the fuel behaves in the whole system of the plant, that data is needed to properly model the behavior that you would expect.

Senator CARPER. Mr. Williams, anything?

Mr. WILLIAMS. No.

Senator CARPER. This has been timely and helpful. As the storm bears down, this reminds us all the more that extreme weather has been coming our way for some time, and it ain't going to stop. We have to figure out how to respond to it, not to just address the symptoms of the problem but also the root cause of the problems creating all this bad weather for our country and our world. This could be part of the solution, not the whole solution but part of the solution. We welcome your input today.

Thank you so much.

Senator BARRASSO. Thank you, Senator Carper, and Senator Whitehouse as well.

Thank all of you for being here to testify. Other members may want to submit follow up questions for the record. The hearing record will be open for 2 weeks.

I want to thank you all for being here, for your time, and your testimony.

This hearing is adjourned.

[Whereupon, at 11:15 a.m., the Committee was adjourned.]