

THE FUTURE OF NUCLEAR POWER

WEDNESDAY, SEPTEMBER 14, 2016

U.S. SENATE,
SUBCOMMITTEE ON ENERGY AND WATER DEVELOPMENT,
COMMITTEE ON APPROPRIATIONS,
Washington, DC.

The subcommittee met at 2:32 p.m., in room SD-138, Dirksen Senate Office Building, Hon. Lamar Alexander (chairman) presiding.

Present: Senators Alexander, Collins, Feinstein, and Udall.
Also Present: Senator Whitehouse.

OPENING STATEMENT OF SENATOR LAMAR ALEXANDER

Senator ALEXANDER. The Subcommittee on Energy and Water Development will please come to order.

This afternoon, we're having the first of two hearings to discuss the future of nuclear power in our own country. We'll have the second one in November or early December.

Today, we'll discuss the importance of nuclear power, the biggest challenges facing it, the status of the Department of Energy's nuclear research and development—and we certainly welcome Secretary Moniz here to help us do that—and things Congress can do to support nuclear power.

In our next hearing, we'll discuss basic energy research and development to support nuclear power, the work that's being done to extend the licenses for existing reactors from 60 to 80 years, development of new advanced nuclear technologies, including small reactors, accident-tolerant fuels, and advanced reactors.

Senator Feinstein and I will each have an opening statement. I'll then recognize any other Senators on the committee for up to 5 minutes for an opening statement, and then we've invited Senator Whitehouse—and we certainly welcome him—to make some remarks at today's hearing. So, we'll turn to him as soon as Senator Feinstein and I make our opening statements, Sheldon, if that's all right with your schedule.

And then Secretary Moniz we'll go to you after that.

Our second panel—and we're delighted to have them and to welcome back Judd Gregg, former United States Senator and Governor from New Hampshire, and the Leadership Chair of nuclear matters, and Jay Faison, founder and CEO of ClearPath Foundation. That'll be the panel after the Secretary of Energy.

THE UNITED STATES WITHOUT NUCLEAR POWER

Today's hearing is about the future of nuclear power, but I want to talk, in my opening remarks, about—I said to Senator Feinstein, I may go 7 or 8 minutes instead of 5, I want to talk about—I want to imagine a day the United States is without nuclear power, a day that I don't want to see in our country's future. That seems like a distant and unlikely scenario, but, in fact, it's more of a threat than many people realize. According to a 2013 report by the Center for Strategic International Studies, up to 25 of our 99 reactors could close by 2020.

And here are some other factors. By 2038—that's 20 years from now—48 reactors will be 60 years old, representing 40 percent of the nuclear generating capacity in the United States. The U.S. could lose half of our reactors if existing licenses can't be extended from 60 to 80 years when those reactors close.

There are nine reactors, three in the Northeast at seven sites, which are scheduled to shut down by 2025. The Energy Information Administration estimates that shutting down these nine reactors will result in a 2-percent increase in total carbon emissions from the U.S. electricity sector. There are four new reactors being built, all in the Southeast.

As an example, Vermont Yankee closed in December of 2014. That was 604 megawatts. It accounted for 70 percent of the electricity generated in Vermont in 2012, although the State only used one-third of its electricity production. In other words, Vermont closed a plant that could have provided 70 percent of its carbon-free electricity—could have amounted to 70 percent of its electricity being carbon-free. Vermont's carbon emissions from its electricity sector increased 5 percent between 2014 and 2015, after Vermont Yankee closed.

Entergy announced it would close the plant in New York, but Exelon bought it and is working to keep it open. There are other examples. In California in 2012, California's carbon emissions reportedly increased approximately 24 percent after closing the San Onofre Nuclear Generating Station in 2012.

The United States uses about 25 percent of all the electricity in the world. Our 99 reactors generate about 20 percent of that electricity. In a time when 20 of the world's leading science academies and many Americans say climate change is a threat and that humans are a significant cause of that threat, nuclear power produces about 60 percent of our country's carbon-free electricity. Power plants produce about 40 percent of the carbon produced in our country.

One way to imagine the United States without nuclear power might be to take a look at the stories of three countries:

First, Japan. After Fukushima, Japan began shutting down its 48 reactors, which provided about 30 percent of its electricity. The cost of generating electricity in Japan increased 56 percent. Major business organizations complained that an earlier restart of the reactors was essential if manufacturing needed to stay in Japan. A Wall Street Journal article reported that the Japanese were turning up their air conditioners to 82 degrees. The Empress and Emperor were wandering around the Imperial Palace at night with

flashlights and candles. Japan has begun to change, and has begun to start some of the reactors.

Second example is Germany. And both these are major industrialized economies like ours. One-quarter of its electricity came from nuclear power, using 17 reactors. Then the government decided to replace them with wind and solar and a cap-and-trade policy. The subsidies for the wind and solar were very high. Another problem was that it didn't produce enough reliable baseload energy for an important manufacturing company, so Germany began not only closing its nuclear power plants, but buying nuclear power from France to replace it, and buying natural gas from a very unreliable supplier—Russia—and in a remarkable turn of events, even began building new coal plants. The cost of electricity in Germany soared, 60 percent.

Finally, there's an example of United Arab Emirates in another direction, a different kind of story. Twelve years after notifying the International Atomic Energy Agency of its intent to build nuclear reactors, the Emirates will have completed four, which will provide nearly 25 percent of its electricity by 2020.

What should the United States do? Well, in summary, one, build more reactors. I said, one time, we should build 100 new reactors. People thought that was just for a shock effect. But, CSIS says that we may close 25 of our 99 reactors by 2020. And the U.S. Energy Information Agency says that about 20 percent of our current capacity from coal is scheduled to go offline by 2020. And if that were entirely replaced by nuclear power, it would require building another 48 new 1250-megawatt reactors, which, by the way, would reduce our carbon emissions another 14 percent.

Number two, solve the nuclear waste stalemate. Senator Feinstein and I don't agree on everything about nuclear power, but we agree on this priority. And I think we agree generally, that we need to move on every path we can to get there. My own view is that we ought to open Yucca Mountain, because the science and the law say we should do it. But, in any event, we have other options—private options, repositories—Senator Feinstein has suggested. Solve the stalemate.

Three, relieve the burdens of extensive regulation. We want to be safe, but we don't want to make it so expensive and difficult to build reactors that we don't build them.

Four, stop picking winners and losers. The subsidy to big wind is so generous that, in some markets, wind producers can literally give their electricity away and still make a profit, and the so-called negative pricing gives such an advantage to wind in a deregulated market that it makes nuclear and coal plants uncompetitive and more likely to close.

And then, fifth, double energy research. That's something the United States does very well. We only spend \$5 billion a year on energy research. We could double that. One way to pay for it would be to go ahead and end the 23-year-old wind subsidy. There's no need to continue to subsidize a mature industry in that way. That would save \$8 billion in authorized funds that we could then put directly into energy research.

So, I believe we need to prepare now by building more reactors, ending the stalemate on what to do about waste, and stopping

Washington from picking winners and losers in the marketplace. We need to push back on excessive regulation and fuel more free-market innovation with government-sponsored research and by encouraging energy diversity. If we do those things, the United States will not see a day without nuclear power, and our energy future will be bright.

Senator Feinstein.

STATEMENT OF SENATOR DIANNE FEINSTEIN

Senator FEINSTEIN. Thanks very much, Mr. Chairman. Thank you for your leadership and for your remarks. As you well know, one of my great pleasures is to be able to work with you. I consider you one of the best in this body. I just want, once again, to say that.

NUCLEAR WASTE

For 5 years, you and I have worked trying to find a solution to our Nation's nuclear waste problem. Unfortunately, though, spent nuclear fuel continues to pile up; 77,000 metric tons, to date, scattered all across our country in spent-fuel pools and dry casks at reactor sites. So, there's no denying that this is a major issue. For me, it's a deterrent to new nuclear power. If we can't properly store the waste, we shouldn't build the reactors.

Approximately 130 million people live within 50 miles of a storage site for nuclear waste. That's more than two out of every five people. In California alone, there are nearly 8,000 highly radioactive spent-fuel assemblies stored in pools and dry casks across four sites, all of which are now shut down or are planning to shut down, leaving behind just the waste. The future of nuclear power, I believe, in this country depends on a solution to the waste problem. Public safety and public acceptance of nuclear power, I believe, depend on it.

I can't just simply continue to support nuclear power generation if there is no strategy for the interim storage and long-term disposal of the waste. I have hoped that, over the past 5 years, you and I and the three Chairs and the two Rankings of the Energy Committee would work to put together a nuclear waste policy bill, and have introduced it, and it hasn't had a hearing, and it hasn't gone anywhere. This is one of my great disappointments.

Unfortunately, the political impasse surrounding Yucca has stalled progress on interim storage. The fact is that Yucca was forced upon elected officials and a citizenry that didn't want it. And that's one of the great learning experiences. The two Senators, along with every other statewide elected official in Nevada, oppose it, so there's no reasonable expectation that their opposition will subside.

So, the lesson of Yucca is that any solution to the nuclear waste issue needs to be voluntary and must have the consent, not only of local governments, but also of the State. We recognize that in our bill, we provide for that in our bill. We know there are areas that would like to apply for these interim waste sites. So, we believe that voluntary acceptance can be developed.

So, regardless of whether one supports Yucca or an alternative consent-based process for creating a long-term storage facility, we

also face a short-term problem. That's why I believe we should be working to establish an interim storage facility away from reactor sites and population centers.

Interim storage is opposed by the House unless it is linked to new funding for Yucca. So, every year, in the Energy and Water Conference discussions, it is dropped from our bill. That's been most unfortunate. The industry can't seem to help themselves on the issue. They've flip-flopped and can't speak with one voice. First they were for consolidated interim storage, then they were against it. There are now 16 shutdown reactors in this country. Seven more shutdowns have been announced. So, it's baffling to me that the industry can't get behind an effort that is so obviously beneficial to them.

In the midst of this debate about how to store spent nuclear fuel, we shouldn't lose sight of the fact that we're dealing with very dangerous materials. The problems at the Waste Isolation Pilot Plant, or WIPP, in New Mexico, are a prime example of the risks we face in nuclear waste. Here we have one of the premier laboratory facilities in the world at Los Alamos making a basic chemistry error on the packaging of waste drums, which led to a radiological release. One mistake in a single drum contaminated more than a third of the entire site. That, to me, is really striking. If we can't trust these experts to handle radioactive waste safely, what confidence can we have in other efforts to manage this material safely and securely, long term, at 78 sites around the country?

There's an article in the LA Times on the WIPP incident. By their estimate, the cumulative cost of cleaning up the contamination, shutdown time, and longer operations could top \$2 billion. For more than 2 years, the cleanup has continued. The Department will miss its goal of reopening the facility in 2016. It has not yet established a new date for when the facility can begin to safely accept waste.

I then am just going to do, for the record, some Fukushima comments that I won't do here, in the interest of time. But, what I say is that we can't allow an accident like Fukushima to happen here in the United States. The industry has spent around 4 billion on Nuclear Regulatory Commission required safety upgrades. And I very much appreciate that. This is just a fraction of how much a disaster on the scale of Fukushima could cost the United States.

In light of these risks and the lack of a storage strategy, I view the risks of improper handling of nuclear materials and accidents to be considerable deterrents to the development of new reactors.

ALTERNATIVE TO NUCLEAR POWER

When it comes to the question of whether there's an alternative to nuclear power that's consistent with our firm intentions to combat climate change, my state—California—is a case in point. In 2013, Southern California Edison permanently shut down its two remaining reactors on the coast, north of San Diego, just south of LA, with 6 million people around it. Each of the two reactors generated 1100 megawatts of electricity. Pacific Gas and Electric, our other major utility, has set upon a course to shut down its two reactors at Diablo Canyon, also 1100 megawatts each. That's a total of 4400 megawatts of nuclear power that will have to be replaced

within 15 years. Within a decade, California will no longer generate nuclear power.

In Southern California, San Onofre was shut down suddenly after problems were exposed with its new steam generators—not like-for-like, but believed to be with new alloys and new construction that would be superior. Despite the sudden loss of baseload power, the utilities and grid operator have been able to maintain reliability. Roughly half of the lost generating capacity will be replaced with renewable energy, energy efficiency, demand response, and energy storage. They serve probably the biggest area in the country.

In Northern California, PG&E decided, this year, that it would not seek to extend Diablo Canyon's operating license beyond 2025. This provides 9 years for an orderly transition for the grid and the surrounding community. PG&E—and its CEO has directly committed this to me—they will replace the lost generating capacity entirely with renewable resources or energy conservation. The context for these power replacement decisions are the laws that the Governor of California has signed, which will bring the largest State in the Union to 33 percent renewable electricity by 2020 and 50 percent renewable electricity by 2030. I believe we will meet that goal. At the same time, the State will double its energy efficiency standards.

Now, these are ambitious goals. California utilities are meeting the challenge by building a clean and more flexible electricity grid. So, in California, we believe we can meet the challenge of climate change without relying on nuclear power. I don't doubt that nuclear power is cheap and efficient, but if we can do that with 40 million people in our State, I believe it also can be done elsewhere in the United States.

My hope has been that we could come to some terms on a nuclear waste facility which would guarantee safety and allow the industry to continue to develop, to invent new reactors, and to be a positive player. I very much regret that 5 years of effort to do that have not been supported by the industry and, essentially, have not been successful.

Thank you very much, Mr. Chairman.

Senator ALEXANDER. Thank you, Senator Feinstein.

Senator Whitehouse, we welcome you to the hearing and have heard your regular speeches about climate change on the Senate floor, and your comments on nuclear power. And we look forward to your testimony.

STATEMENT OF SENATOR SHELDON WHITEHOUSE

Senator WHITEHOUSE. Thank you, Chairman Alexander and Ranking Member Feinstein, for inviting me to speak at today's hearing.

NUCLEAR ENERGY REFORMS

The past year has seen a renewed and bipartisan interest in nuclear energy reforms. I'm part of the bipartisan effort behind two bills this Congress. The first, the Nuclear Energy Innovation Capabilities Act, was approved 87-to-4 as an amendment to the broader energy bill that passed the Senate, and it's now being debated in

conference. This bill would create a new nuclear innovation program through the Department of Energy that would function as a shared nuclear science clearinghouse for Federal agencies and private industry. It would open up the National Labs testbed facilities to private industry, to create partnerships between the Federal Government and academia in early stages of reactor development, and foster greater market certainty for investors.

The second bill is led by my friend and colleague, Senator Inhofe, Chairman of the Environment and Public Works Committee, and is coauthored by Senators Crapo and Booker. This bill, which looks to reform the Nuclear Regulatory Commission, recently cleared the Environment and Public Works Committee on a vote of 17-to-3. The House of Representatives recently passed a similar measure under suspension of the rules. Our bill would create a new advanced reactor licensing framework for concepts that are much different than today's light water reactors. As cosponsors, we agree NRC's (Nuclear Regulatory Commission) current licensing framework is not designed to promote a next wave of advanced nuclear technology.

The purpose of these two bills is straightforward: drive home-grown innovation of next-generation nuclear technologies in our National Labs, and put in place a regulatory framework that is better suited to license these technologies. We shouldn't sit back and watch investors go to China and India to develop and commercialize next-generation reactors. This is an opportunity to give American businesses a leg up in that international marketplace.

ADVANCED REACTOR DESIGNS

Our bipartisan group laid out our support for advanced reactors in a U.S. News & World Report op-ed, which I would offer to submit as part of the record of this hearing.

As we wrote, new advanced reactor designs can substantially reduce the threat of a meltdown. In addition, many new designs are much smaller than their predecessors, simplifying and standardizing construction. Smaller size means they can plug into future micro-grid systems, reducing the need for massive transmission system upgrades.

Perhaps the most interesting features are that the advanced technologies could actually reduce nuclear waste created by the current light water fleet. Dealing with our existing nuclear waste stockpile remains an unresolved and important issue. And the holy grail for me in this effort would be to have these advanced reactors be part of that solution.

Research on advanced nuclear reactors will help us address one of the most critical issues of our time: climate change. There is clear consensus about the urgent need to address climate change—from the American public, from every single major American scientific society, from most major American nameplate companies, other than those in the fossil fuel business, from every single American National Lab and NASA and NOAA, from America's national security, military, and intelligence leaders, and of course, from the Pope and other world leaders. The United States Congress is fast becoming a laughingstock in its denial of this problem.

Advanced nuclear technologies could be a key part of a low carbon energy future. A recent study by Columbia University environmental economist Jeffrey Heel of the feasible pathways to an 80-percent reduction of U.S. greenhouse gas emissions below 2005 levels by 2050 found that the cheapest way to get there requires nuclear to play a role. The common ground we have established this year, I believe, is only the beginning. There are other areas that can benefit from the same bipartisan spirit, including working to preserve our existing nuclear fleet in the safest possible way. It makes no sense to close a safely operating nuclear plant just because, economically, it receives no value for the zero-carbon quality of its power, when we know there is value to that zero-carbon quality.

So, Mr. Chairman, Ranking Member, let's make progress where we can. Thank you very much.

Senator ALEXANDER. Thank you, Senator Whitehouse. And as one Senator, I look forward to working with you. Senator Feinstein agreed—and I agree, certainly—on the importance of finding a repository. I also agree with you about the importance of finding ways to deal with climate change. If 20 of the leading science agencies in the industrialized countries of the world have said it's a threat and that humans are helping to cause it—if 20 fire marshals of that repute came to my house and said, "Your house is likely to catch fire," I think I'd buy some insurance. So, as you and I have discussed, 10 years ago I suggested a power-plants-only plan to deal with carbon.

So, I think there is some area for agreement here among those of us who believe that nuclear power is an important part of the future of the country, and those who agree that climate change is a threat, and those who believe in both those things. So, we especially welcome your participation now and in the future.

Senator WHITEHOUSE. Well, thank you, Chairman. You are also my Chairman on the Health, Education, Labor, and Pensions Committee, where it has been a real pleasure working with you. So, I second the kind remarks and compliments of the Ranking Member. Thank you, Chairman.

Senator ALEXANDER. Now, Senator Feinstein and Secretary Moniz, the vote is well underway, and there are two votes. So, I think the best thing to do is to adjourn the hearing briefly. Senator Feinstein and I will go to the floor and be the last to cast votes on the first vote, and the first on the second vote. There might be three votes. And then we'll come right back. So, that means we'll adjourn for about 20 or 25 minutes, and then we'll come back and we'll be able to hear your testimony and ask you questions. Other members of the Senate, after the vote, will be able to come in and do the same.

So, Senator Feinstein, if that's all right with you.

Senator FEINSTEIN. That's fine with me. I really hope that Secretary Moniz will not mind this. I mean, it's the vicissitude of the conditions we can't control. And you've been so terrific. You know, we don't want to have you have to stand around. But—

Secretary MONIZ. Well, I appreciate that, but I also appreciate that we have a compressed schedule this month and you need to vote.

Senator FEINSTEIN. Thank you.

Senator ALEXANDER. Thank you.

The subcommittee stands in recess, subject to the call of the Chair. We'll see you in about 20 minutes, hopefully.

DEPARTMENT OF ENERGY

OFFICE OF THE SECRETARY

Senator ALEXANDER. Subcommittee will now please come to order.

I now welcome and recognize Secretary Moniz to provide his statement on behalf of the Department of Energy.

Secretary, your full written statement will be included in the record. We look forward to your testimony, and appreciate your making time today. Please proceed.

STATEMENT OF DR. ERNEST J. MONIZ, SECRETARY

Secretary MONIZ. Well, thank you, Chairman Alexander, Ranking Member Feinstein, for the opportunity to come here to discuss nuclear energy.

As we all know, nuclear power contributes, as you've said, about 20 percent of our electricity, and importantly, over 60 percent of our non-greenhouse-gas-emitting power. An active nuclear enterprise also supports our global leadership in nuclear nonproliferation, another area, of course, in which the Department is very engaged.

INTERNATIONAL MARKET

I would just add that, of course, the Paris Agreement and our Mission Innovation initiative also indicate the enormous international market that's going to grow for all kinds of clean energy technology. And that, of course, will include nuclear energy. One part of that could very well be small modular reactors, a vital part of that innovation agenda and of the low carbon future.

SMR LICENSING TECHNICAL SUPPORT PROGRAM

The Department's SMR Licensing Technical Support Program expects that our reactor design partner, NuScale, will submit the first SMR (Small Modular Reactor) design certification application by the end of the calendar year, and the DOE (Department of Energy) is now working with partners in Idaho and Tennessee on potential SMR development projects as part of our innovation agenda.

REACTOR LIFE EXTENSION

We're also developing the scientific basis to extend the life of existing reactors—you referred to that earlier—through research on materials aging and degradation, digital modernization, and development of accident-tolerant fuels.

CONSORTIUM FOR THE ADVANCED SIMULATION OF LIGHT WATER
REACTORS

Also, in your part of the world, at Oak Ridge, the first innovation hub, CASL (Consortium for the Advanced Simulation of Light Water Reactors), is doing extremely well, in terms of developing the simulation tools for reactors, indeed releasing products for virtual reactor design.

PRIVATE-SECTOR NUCLEAR RESEARCH AND DEVELOPMENT

We are also seeing, very interestingly, significant private-sector nuclear technology R&D, Third Way, identifying almost 50 companies and institutions doing nuclear energy innovation, which is a remarkable turnabout over the last several years. A major focus for us will be providing the technical support and infrastructure access to these entrepreneurs, not unlike what Senator Whitehouse described in one of those bills. I would note that DOE's GAIN Initiative also recently announced eight small businesses in this arena will receive about \$2 million and access to the National Labs and Nuclear Science User Facility partners.

RESEARCH AND DEVELOPMENT

Earlier this year, we announced awards to two companies developing one high-temperature gas reactor and another molten salt reactor concepts. A robust RD&D program depends on an infrastructure of experimental and computational facilities and skilled scientists and engineers. The Department supports a broad range of such facilities, from small-scale laboratories to hot cells and test reactors to 25 university research reactors to high-performance computation for a broad program.

CROSSCUTTING INITIATIVES

In addition to these very specific nuclear energy programs in the innovation space, we have several crosscutting initiatives—that is, initiatives that cut across our energy and science programs—that are directly germane to nuclear energy innovation. That includes an advanced materials initiative in the fiscal year 2017 budget, our supercritical CO₂ cycle development, which is now led out of fossil energy, but includes nuclear energy, and our Exascale computing initiative and our subsurface crosscutting science and engineering activity relevant to nuclear waste.

LOAN PROGRAM OFFICE

Finally, DOE's Loan Programs Office plays an important role in this space. The Vogtle Plant, under construction in Georgia, was partially financed using an \$8.3 billion loan guarantee, and a new solicitation first issued in December 2014 will support up to \$12.5 billion in loans for advanced nuclear projects, potentially including small modular reactors.

TASK FORCE

Now, to help shape a decades-long vision for advanced reactor development and deployment, I also established a task force of the Secretary of Energy Advisory Board. They've worked very, very hard and I anticipate a report at the September 22nd meeting that is coming up next week.

All in all, we have a robust, multidimensional nuclear energy innovation program that can be expanded further as we seek the kind of increase in the innovation budgets that you discussed earlier.

EXISTING PLANTS AND ENERGY MARKETS

Turning to existing plants and the energy markets, we have 99 operating reactors. We will soon add the Watts Bar 2 Reactor. And there are the four additional reactors at Vogtle and Summer that are being built and should operate by the end of this decade. All four of those reactors being the AP-1000 generation-3 or generation-3+ reactors.

However, significant challenges and complex market factors do face the existing nuclear fleet, particularly in restructured markets. We run the risk that many will close just as we are trying to ramp up low carbon energy sources, for example, to meet State implementation goals for the Clean Power Plan.

Here on Capitol Hill, in May, we convened experts and stakeholders to discuss potential Federal and State actions to prevent at least some of these early closures. And in addition to the DOE research efforts I have mentioned, which would be more of a mid- to longer-term impact, FERC (Federal Energy Regulatory Commission) has now been working diligently on issues of price formation, which can be important for the existing nuclear plants.

At the State level, options for action include power purchase agreements, tax credits, and clean energy standards. And, of course, in August, New York established a clean energy standard to give zero emission credits to some of the State's nuclear power plants. That, together with the purchase of one of those plants, will result in the continuation of three nuclear power plants in Upstate New York. Illinois is considering similar measures.

And finally, I'll add that our ongoing Quadrennial Energy Review second installment is taking on the challenge of valuation for benefits in the electricity system, including the national security benefits of a vibrant nuclear industry. So, this question of valuations, of price formations as to how generators are rewarded, is clearly very important.

NUCLEAR WASTE STRATEGY

Finally, I would just turn to nuclear waste strategy. I agree, certainly, with Senator Feinstein that we must find a sustainable path forward for the storage and disposal of nuclear waste. And to achieve an integrated waste management system, the Department is clearly focusing on a consent-based siting process, as you said.

DOE issued an invitation for public comment in December 2015, followed by a kickoff this year in eight public meetings across the United States. The Department will discuss this feedback and next steps for a consent-based siting effort at a long-scheduled public meeting that will be held here tomorrow in Washington, D.C.

By the end of the calendar year 2016, the Department will issue a number of documents, including a draft consent-based siting process benefiting from these regional meetings, as well as siting considerations for interim storage facilities and deep geologic repositories. Our fiscal year 2017 budget proposes \$39.4 million to support our efforts, continuing to move forward with a consent-based approach to siting storage and disposal facilities, including \$25 million for grants to States, tribal nations, and local governments.

In parallel with developing a consent-based approach to siting, the Department is developing the concept of consolidated interim storage, as you have both discussed. A pilot facility and, subsequently, a consolidated interim storage facility with greater capacity and greater capabilities would, (1) allow the permanent removal of spent fuel from shutdown sites, (2) allow the Federal Government to begin meeting its contractual waste management commitments, (3) provide crucial flexibility for the overall nuclear waste management system, and (4) provide useful experience, including opportunities to conduct R&D on the behavior of spent nuclear fuel and high-level radioactive waste over time. So, there are many benefits in the interim storage addition to our waste management system.

DOE would need congressional authorization to construct an interim storage facility. However, in parallel, with efforts to develop DOE constructed and operated facility concepts, we have seen the emergence of private initiatives that may provide interim storage services. And this is a very interesting development. We are preparing to seek public input on how a privately owned storage facility could fit into the overall integrated waste management system, specifically planning to issue an RFI (Request for Information) within weeks.

The Department continues to also work toward a permanent disposal solution, seeking to better understand different methods and geologies that can effectively isolate spent fuel and high-level waste for thousands of years into the future.

DOE is also pursuing our planned deep borehole field test to determine the feasibility of using the deep borehole approach as an alternative to mined geological repositories for certain disposal pathways—not as a replacement, but as a supplement.

We have recently received letters of intent to submit proposals that indicate there is continued strong interest. Full proposals are due October 21st, with plans to select one or more of those applicants early in 2017. And, in fact, yesterday there was a proposal conference, which had about 20 people, and about 12 companies engaged.

DOE is also developing plans for a defense waste repository. Unlike commercial spent fuel, defense inventory is no longer growing. Some defense waste is less radioactive. It's cooler, easier to handle than commercial fuel. And this could allow for some different, simpler, and maybe faster pathways for disposal. We expect to seek public comment and feedback on a defense waste repository as well later this calendar year.

Overall, our budget proposes \$76.3 million for integrated waste management system activities, a \$53.8 million increase from fiscal year 16, showing our priority in moving forward on these pathways, working towards waste storage and disposal solutions. That's in addition to \$74 million for used nuclear fuel disposition R&D.

So, in conclusion, again, I appreciate the opportunity to discuss nuclear energy as a vital component of our energy strategy and how we are moving forward, and frankly, setting the table for a new administration and Congress in about—just over 100 days.

Thank you. I would be happy to answer questions.

[The statement follows:]

PREPARED STATEMENT OF DR. ERNEST J. MONIZ

Chairman Alexander, Ranking Member Feinstein, and members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the future of nuclear energy in the United States.

For the past two decades, nuclear power has reliably and economically contributed nearly 20 percent of electricity generated in the United States. It produces more than 60 percent of our non-greenhouse-gas emitting power, making nuclear energy our Nation's single largest contributor of carbon-free electricity, and as such is responsible for avoiding hundreds of millions of tonnes of carbon dioxide emissions each year. Under President Obama's Clean Power Plan, the goal is a reduction of carbon dioxide emissions by 32 percent below 2005 levels by 2030. A strong domestic nuclear energy sector could help with meeting this goal and is also critical for the U.S. to continue as a global leader in nuclear nonproliferation.

The Paris Agreement and Mission Innovation, both announced at the 2015 United Nations Climate Change Conference (COP21), have shown the enormous international interest for low-carbon technologies including nuclear energy, the need to accelerate clean energy innovation, and the potential for U.S. industry to develop these advanced technologies.

A prerequisite for nuclear power continuing as a vital part of the Nation's clean energy portfolio is public confidence in the safety of nuclear plants and commercial confidence that the plants can be operated safely, reliably, and economically. Additionally, we have an obligation to develop a workable, long-term solution for storage and disposal of spent nuclear fuel and high-level radioactive waste.

INNOVATION

The Department supports innovation across all energy technologies, and we are involved in the entire nuclear energy lifecycle. This includes supporting research, development, and licensing of new technologies; providing infrastructure for testing and experimentation; working with industry to support the safe, reliable and economical operation of today's nuclear plants; and advancing the Administration's Strategy for the Management and Disposal of Used Nuclear Fuel and High-level Radioactive Waste.

Mission Innovation, an initiative launched in November 2015 by the U.S. and 19 other countries represents an unprecedented commitment to accelerate global clean energy innovation. The Department's fiscal year 2017 request invests in key areas to support this initiative. The Department's fiscal year 2017 Budget Request invests in key areas to accelerate investment in nuclear energy innovation. Specifically, the fiscal year 2017 request includes \$994 million for the Office of Nuclear Energy's research and development (R&D) programs, \$8 million above fiscal year 2016. These investments include advancing technologies that support the existing reactor fleet and that develop new, next-generation options. Of this total, the fiscal year 2017 Budget Request for the Office of Nuclear Energy includes \$804 million in support of Mission Innovation.

Improvements in Light Water Reactor Technology

Our Nation's existing nuclear power fleet consists of 99 operating light water reactors (LWR), and the Department's programs advance LWR technologies in a variety of ways to support the existing fleet's continuing role providing reliable low-carbon power for the United States.

The Light Water Reactor Sustainability Program is developing the scientific basis to extend the life of our existing nuclear reactor fleet while also improving economics and reliability and sustaining safety and security through research on materials aging and degradation, safety margin characterization, and digital modernization technologies. The Department also is working on enhancing the accident tolerance of light water reactors through cost-shared efforts to develop advanced accident tolerant fuels for existing commercial nuclear power plants with improved safety and performance characteristics.

We have been successful in improving modeling and simulation to enhance the performance of currently operating light water reactors through the Consortium for Advanced Simulation of Light Water Reactors (CASL), one of the Department's Energy Innovation Hubs, and a program I was honored to serve as the Chairman of the Board for its first 2 years. Established in 2010 and centered at the Oak Ridge National Lab, CASL uses the Department's most advanced computing infrastructure to model and simulate a Virtual Environment for Reactor Applications (VERA) that is being used to understand performance and safety issues of currently operating Pressurized Water Reactors. VERA has been used to simulate the full operating history of the Watts Bar Nuclear Power Plant Unit 1 Pressurized Water Reactor in

Spring City, Tennessee. This simulation included high-fidelity predictions of more than 18 years of reactor operations including fuel loading, depletion, shuffling, and discharge. The results have been compared with measured plant data and showed a high degree of consistency. CASL is working with Westinghouse, one of their founding partners, to use VERA to simulate the startup of the AP1000 reactor to confirm their engineering calculations.

Currently in its second and final phase, CASL will enhance the development of VERA for applications beyond pressurized water reactors, to include boiling water reactors and new reactor designs like small modular reactors.

Small Modular Reactors

Small modular reactors (SMRs) are one area in which we are seeing rapid innovation, with several companies researching light water SMR designs in the United States.

SMRs have the potential to offer a new standard of passive nuclear safety with designs that safely shutdown without operator interaction, off-site power, or off-site water. They may also offer greater affordability by requiring potentially lower upfront capital cost investments than traditional gigawatt-scale nuclear plants, and potentially shorter construction times through factory fabrication. DOE sees SMRs as a vital part of the world's low-carbon future, including the United States.

The Department's SMR Licensing Technical Support program was created to realize these and other benefits by advancing the first domestic SMR designs. DOE's cost-shared investment has generated progress, and we expect that our reactor design partner, NuScale, is expected to submit the first SMR design certification application to the U.S. Nuclear Regulatory Commission by the end of the calendar year. Fiscal year 2017 will be the final year of funding for SMR LTS activities.

SMRs may also offer an important new option for power generation in a variety of settings. For one of our site partners, the Utah Associated Municipal Power Systems (UAMPS), SMRs may be an option to replace the power from retiring coal plants in the mid-2020s. UAMPS has identified a preferred site on Federal land at the Idaho National Laboratory to potentially build a NuScale SMR. Our other site partner, the Tennessee Valley Authority, has submitted an early site permit application to the U.S. Nuclear Regulatory Commission for an SMR project at the Clinch River site that could deliver highly-reliable power to ratepayers in the Tennessee Valley region. The Idaho National Laboratory has been investigating how SMRs could be part of a hybrid energy system demonstration along with renewable energy sources.

Several factors, however, pose challenges to the path to deployment for SMRs, including the current low price of electricity and low electricity demand growth.

Further, the production tax credits (PTC) enacted by the Energy Policy Act of 2005 that are available to new nuclear power plants would likely not apply to the first SMR deployments because SMRs would begin operation after the nuclear PTC sunset of December 2020, and because current law does not include a statutory mechanism for non-profit SMR owners to take advantage of the credits through transfers.

In light of the progress and the challenges, DOE continues to study the path to deployment of SMRs. As part of that effort, DOE held a public workshop on June 22–23, 2016 to solicit industry input, and we expect a summary report from that workshop to be available in October 2016.

Executive Order 13693 set clean energy targets for Federal facilities to meet over the subsequent decade and SMRs are among the set of technologies that count towards meeting those targets. DOE is currently conducting a study to enumerate and analyze the various legal authorities available to it and other Federal agencies to meet the clean targets set out in Executive Order 13693, including utilizing power from SMRs.

Advanced Reactor Concepts

Across all areas of nuclear reactor technology, we are now seeing a considerable focus by American industry to invest in the development of novel nuclear reactor concepts—almost 50 companies and institutions are working on nuclear innovation, according to a study by Third Way.¹ This level of activity in industry on novel ideas is a new development with potentially significant implications for the future of nuclear power in the U.S.

¹Todd Allen, Matt Goldberg, Amber Robson, and Kemal Pasamehmetoglu (Idaho National Lab), "What's Missing in U.S. Nuclear? An Innovation Culture," Third Way, March 29, 2016. Accessed September 9, 2016. Available at: <http://www.thirdway.org/report/whats-missing-in-us-nuclear-an-innovation-culture>.

To help take advantage of this industry focus, DOE started this year the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative to make DOE's nuclear energy research capabilities accessible to industry engineers and scientists in a public-private partnership. The opportunities available through GAIN include: access to nuclear and radiological facilities and testing capabilities (e.g. thermal-hydraulic loops, control systems testing, etc.); computational capabilities including state-of-the-art modeling and simulation tools; information and data through a knowledge and validation center. In June, the GAIN program announced that eight small businesses will be provided up to \$2 million for the Nuclear Energy Voucher pilot program, granting them access to the extensive nuclear research capabilities available at DOE's national laboratories and Nuclear Science User Facilities (NSUF) partners.

The Department's ongoing advanced reactor programs specifically support research to develop technologies for advanced concepts—Generation IV designs—that could dramatically improve nuclear power performance in sustainability, economics, safety, and proliferation resistance. Next-generation concepts each have potential significant advantages: high-temperature gas-cooled reactors (HTGR) could provide higher-efficiency power generation and high quality process heat for industry, thereby reducing carbon emissions; liquid metal-cooled fast reactors could be used to generate electricity while addressing long-lived nuclear waste issues; fluoride salt-cooled high-temperature reactors (FHRs) could have the high temperature capabilities of HTGRs while operating at atmospheric pressure; and innovations like tristructural-isotropic (TRISO) coated particle fuel and graphite core structural components could allow for advanced designs with extremely high safety margins in all imaginable scenarios.

In fiscal year 2016, Congress appropriated \$12.5 million for two ongoing industry cost-shared awards to further the development of two performance based advanced reactor concepts. Earlier this year, DOE announced awards to two companies, X-energy and Southern Company, seeking to develop such novel reactor concepts. These awards will support two new designs with advantages in safety, operations, and economics from companies who presented clear plans for demonstration of these concepts in the 2030's. These two designs, an advanced pebble bed HTGR and a molten chloride fast reactor, are among many with significant potential for performance advantages for the next generation of nuclear power reactors.

The final step in bringing these novel technologies to market will be obtaining certification and licensing by the Nuclear Regulatory Commission (NRC). Most commercial reactor types licensed to date in the U.S. have had designs using water as the primary heat transfer medium. A joint DOE-NRC initiative supports development of Advanced Reactor Design Criteria (ARDC) for Nuclear Power Plants with advanced reactor designs, specifically addressing the safety and operating characteristics of reactors with non-water coolants. The NRC has released draft ARDC for public comment and plans to hold another public meeting later this year and intends to have regulation guidelines finalized by the end of 2017. This key activity is important for the potential of these novel concepts to be realized.

Nuclear Energy Infrastructure

A robust research, development, and demonstration program depends on an infrastructure of experimental facilities, computational facilities, and highly trained scientists and engineers dedicated to meeting the needs of the Nation. The Department supports a nuclear research infrastructure across the Nation incorporating a broad range of facilities, from small-scale laboratories to hot cells and test reactors. Computing facilities, ranging from desktop workstations to highly-parallel supercomputers at the national laboratories, are routinely employed to gain new insights and guide experiment design.

The fiscal year 2017 budget proposes \$102 million to support DOE nuclear test reactors at the Idaho National Laboratory (INL), including strategic investments at the Advanced Test Reactor (ATR) to improve reliability and availability, and refurbishments to major Transient Reactor Test (TREAT) Facility systems to support restart efforts. Both facilities play a critical role in meeting nuclear reactor technology R&D program objectives. The fiscal year 2017 budget also proposes \$75 million for sustainment of unique nuclear and radiological R&D capabilities at the Materials and Fuels Complex (MFC) at INL that are required for examination, characterization, fabrication, and separation of materials, components, and fuels.

The High Flux Isotope Reactor (HFIR) at the Oak Ridge National Laboratory also is an important component of DOE's Nuclear Science User Facilities (NSUF), which have a singular focus on advancing technologies supporting nuclear energy applications. HFIR is a versatile 85 MW research reactor offering the highest steady-state neutron flux in the western world. It is able to quickly generate isotopes that re-

quire multiple neutron captures and perform materials irradiations that simulate lifetimes of power reactor use in a fraction of the time. Each year, NSUF conducts a rigorous competitive process leading to awards providing university, national laboratory and industry principal investigators no-cost access to the unique NSUF research capabilities, including HFIR.

The Department supports 25 university research reactors located at 24 U.S. universities that provide significant in-core fuels and materials irradiation experiment capabilities as well as hands on teaching tools for hundreds of students each year. The Department's fiscal year 2017 Budget Request includes \$7 million to continue providing fresh and used nuclear fuel services for these reactors, in addition to funds for university reactor-supported research each year. In fiscal year 2017, the Department will also complete a multi-year \$15 million investment to complete safety upgrades at the TRIGA International fuel production facility in France to ensure a continuing and stable fuel source for the 12 U.S. university TRIGA research reactors, and many more such reactors world-wide.

Crosscutting and Other Innovation Initiatives

The Department also supports innovation of nuclear energy technologies through a variety of other initiatives outside of the Office of Nuclear Energy.

Several of our Crosscutting Initiatives, which harness funding and capabilities from many DOE program offices to advance key science and technology objectives with impact across DOE's missions, can support the advancement of some nuclear energy technologies. In fiscal year 2017, the Advanced Materials crosscutting initiative will coordinate \$113 million across five DOE program offices to advance innovation for affordable, reliable, high performance materials—a key to next-generation nuclear technologies. The Subsurface Crosscutting Initiative will coordinate \$258 million in R&D investment across five program offices at DOE to advance science, technology and engineering in the subsurface, which could benefit nuclear waste disposal. Our Supercritical CO₂ Crosscutting Initiative is advancing a technology that could significantly improve the efficiency of future, generation IV nuclear plants—improving both their capital and operating costs. Our Exascale Computing Crosscutting Initiative continues to support activities, such as CASL, by significantly accelerating the development and deployment of high performance computing capabilities.

DOE's Loan Programs Office also plays an important role in the deployment of innovative nuclear reactor designs. The Vogtle Plant, now under construction in Georgia, was financed using \$8.3 billion in DOE loan guarantees to support construction of the facility. These newly constructed units will provide enough reliable, zero-carbon, baseload electricity to power 1.5 million homes in the Southeastern United States. In addition, a new solicitation, first issued in December 2014, will support up to \$12.5 billion in loans for advanced nuclear projects in the U.S., potentially including small modular reactors to help jumpstart this innovative new area.

The Nuclear Energy Workforce

To maintain and grow its vibrant domestic nuclear energy industry while continuing its global leadership in nuclear nonproliferation, the U.S. requires a strong domestic workforce of nuclear scientists and engineers.

DOE engages with industry to address workforce needs. The Integrated University Program at DOE has funded each year approximately 30 multi-year student fellowships and 46 single-year scholarships in the nuclear engineering and science fields of study. Since 2009, this program has awarded nearly \$25 million to more than 500 students for nuclear energy-related scholarships and fellowships. Ninety-eight percent of the students who have completed nuclear energy-related fellowships have subsequently pursued careers in nuclear energy fields at the Department's national laboratories, other government agencies, academic institutions or private companies.

DOE implemented in fiscal year 2016 a Nuclear Energy Traineeship initiative to address priority nuclear energy workforce needs in critical areas of science, technology, engineering, and mathematics (STEM) to advance critical disciplines and competencies necessary for DOE's nuclear energy mission responsibility. The \$3 million Traineeship in Radiochemistry, which was recently awarded to a consortium led by Washington State University, is the Department's first jointly-funded traineeship, supported by \$2 million from the Office of Nuclear Energy and \$1 million from the Office of Environmental Management. The Office of Nuclear Energy requested \$1 million for fiscal year 2017 to produce a study on areas where the market is not providing sufficient educational resources for specific nuclear fields and why those market failures exist.

Finally, at any given time, between 400–500 university students are participating in university-led research funded by the Office of Nuclear Energy, helping to provide diverse thought and capabilities to these activities and to develop the future nuclear workforce.

The Path Ahead for Nuclear Energy Innovation

Accelerating nuclear energy innovation and ensuring the commercialization of those new technologies will require a decades-long vision. To that end, in 2014, I established a Task Force of the Secretary of Energy Advisory Board (SEAB) to focus on the Future of Nuclear Power.

The Task Force's principal charge is to develop a report that will describe the landscape to go from today's reliance largely on light water reactors to a situation from 2030 to 2050 where one or many nuclear technologies have reached technical and commercial maturity and are deploying at a rate that could contribute carbon free nuclear power for 20 percent of global electricity generation. This report could include historical operating performance; evolving end-user requirements such as process heat, hydrogen production, and desalination; options for new development and test facilities; and reactor design and development.

I expect the report to be discussed at the upcoming SEAB meeting on September 22 and look forward to its recommendations informing this conversation.

EXISTING PLANTS AND THE ENERGY MARKET LANDSCAPE

Status of the Current Fleet

As I mentioned previously, there are currently 99 reactors operating in the United States, totaling 99 gigawatts-electric (GWe) of capacity. As already stated, this nuclear fleet is the largest part of America's clean, emission-free electricity generation, with these reactors provide about 20 percent of electricity in the United States and approximately 60 percent of our zero-carbon electric generation. Nuclear power plants provide reliable power, maintaining the highest capacity factors of all electricity generators.

In May 2016, the Tennessee Valley Authority's Watts Bar Unit 2 achieved criticality, and in June 2016, it produced power for the first time and is currently undergoing start-up testing with commercial operation planned for the fall of 2016. It is the United States' first new commercial nuclear generation in the 21st century. Additionally, two Vogtle units in Georgia are scheduled to come on-line in 2019 and 2020 respectively. Construction of two new AP-1000 units at V.C. Summer in South Carolina are also under construction.

Market Structure and Early Closures

In spite of the good news associated with these new nuclear plants, there are significant challenges facing the existing nuclear fleet. In just the past 4 years, five reactors have shut down earlier than the end of their licensed operating period and even more have announced intentions to close early. The shutdown of these power plants eliminates needed zero-carbon electricity generation just as states begin design of Clean Power Plan implementation.

The challenges facing operation of these plants are largely due to a combination of complex market factors. Inexpensive electricity prices driven primarily by low natural gas prices, low demand growth, and other market factors have made operating nuclear power plants uneconomical in some parts of the country.

The current fleet of reactors was built under a very different market structure: cost-of-service regulated utilities that incentivize large capital investments. 54 GWe of the current generating capacity is in regulated markets, with the rest in restructured electricity markets, and all five new plants are in regulated markets. Today, however, many nuclear reactors have to compete in wholesale power markets, and some reactors with higher operating costs—especially single-unit, smaller plants—are struggling. Several more reactors may be at risk of early closure due to these economic forces and the increasing costs of operation.

The Federal Energy Regulatory Commission (FERC) is working on reconsideration of price formation—or how electricity prices are established to balance supply and demand. Following several workshops in the Fall of 2014 and following extensive industry response, FERC required the regional transmission organizations and independent system operators to submit reports considering a number of potential issues for improving the function and transparency of pricing in electricity markets. FERC has also docketed several proposed and final rules with new market requirements that reconsider price formation principles. Actions like these could ultimately help appropriately price the value nuclear plants offer, which could in turn help their economics.

At DOE, we have been using our convening power to advance the conversation. In May 2016, I convened a meeting of experts and stakeholders in the nearby Hart Senate Office Building to discuss these economic challenges and the unintended consequences that could arise from early closures. I appreciate that Senator Crapo hosted this event and that both he and Senator Booker participated and provided remarks. At the meeting, we identified potential policy options that can be pursued at Federal and state levels to address these concerns, as well as technical options that utilities can use to improve the economic competitiveness of operating nuclear power plants.

Actions at the State level were also discussed in the May meeting, including power purchase agreements, tax credits, and clean energy standards, and some are now being implemented. In August, New York established a Clean Energy Standard that will give Zero Emission Credits to some of the State's nuclear power plants. This action has the potential to keep open three plants that were all at risk of closure. In Illinois, a similar clean energy standard is under consideration by the State, which has the potential to keep open about 3 GWe of clean electricity generation. As States struggle with these energy related issues, we in DOE are available to provide technical assistance as needed.

DOE's research programs are also working in a number of areas that may begin having an impact in the 2020 timeframe to address longer-term solutions to these issues. DOE is supporting R&D jointly with industry through the Light Water Reactor Sustainability Program, Accident Tolerant Fuel development, and CASL that can enable plant performance gains and reduce operating costs. DOE recently convened a panel of experts from industry, national laboratories, academia, and regulators to identify research, development, and demonstration opportunities that could prove economically beneficial, an effort that highlighted the potential improve materials—already an area of emphasis for DOE's R&D programs. Lastly, our joint work between the Office of Nuclear Energy and Energy Efficiency and Renewable Energy in nuclear-hybrid systems has the potential to further improve the economics of nuclear power.

Clean Power Plan

The Clean Power Plan can also benefit the existing nuclear fleet—although with implementation a few years off, bridge solutions may still be required in the near-term. The plan is projected to reduce greenhouse gas emissions from the power sector by 32 percent versus 2005 levels by 2030. Its limits on carbon pollution from fossil fuel power plans help by taking the cost of that pollution into account, enabling the market to internalize the value of zero-emitting sources like nuclear.

Under the Plan, the EPA's targets for each state provide tremendous flexibility in implementation, leaving it up to the states to determine incentives for the existing nuclear fleet. For example, the Clean Power Plan allows either mass-based or rate-based approaches for compliance. Under a mass-based approach, states can choose whether to cover new as well as existing fossil fuel plants. By covering new as well as existing coal and gas plants, a state would provide the greatest incentive for the nuclear fleet because it most clearly reflects the value of zero-emitting sources.

Quadrennial Energy Review and Valuation

The crux of the challenge for owners and regulators is economic. Taking into account the climate benefits and the potential value of baseload power, the benefits of nuclear power can outweigh the costs of operating our nuclear fleet. This alignment requires characterizing and pricing the benefits and costs provided by all electricity resources to determine an optimal generation mix for the various regions across the United States. Some benefits are regional, such as grid stability, while others are national, such as improved energy security.

The first installment of the Quadrennial Energy Review (QER) included a recommendation to appropriately value electricity services and technologies. We are acting on this recommendation in our Quadrennial Energy Review 1.2, which is focused on electricity from generation to end-use. We are focused not just on valuing new grid services and technologies, but also on understanding how existing assets—like nuclear plants—should be valued as the grid's physical and institutional structures evolve. Decisions about energy tariffs, policies, and market structures should consider a full suite of value streams, including reliability, flexibility, resilience, environmental benefits, security, and others.

Some value streams that nuclear plants provide, like carbon-free electricity and high availability, are either not valued completely or are valued differently across jurisdictions. As a result, nuclear plants are not always fully valued through elec-

tricity prices. Changes in capacity markets to reward capacity performance are a step in the right direction toward valuing firm capacity.

We also must remember that maintaining a vibrant nuclear industry is important for national security. It is important for the United States to serve a major role in setting international standards of safeguards, physical security, nonproliferation, and safety; we must be a major player in domestic nuclear energy. These and other valuation issues are central to the analysis we are doing for the next installation of the QER.

NUCLEAR WASTE STRATEGY

To help ensure the long-term contribution of nuclear power in meeting the Nation's energy needs and to fulfill the Federal Government's responsibility to manage the more than 75,000 tons of waste accumulated over decades of defense activities and clean energy production, we must find a sustainable path forward for the storage and disposal of nuclear waste.

As outlined in the Administration's Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste, the Department is planning for an integrated waste management system to transport, store, and dispose of spent nuclear fuel and high-level radioactive waste from commercial electricity generation, as well as national defense and research and development activities.

Consent-Based Siting

To achieve an integrated waste management system, the Department is developing a consent-based siting process to help work collaboratively with the public, communities, stakeholders, and governments at the local, state, and tribal levels. In fiscal year 2016, the Department launched an effort to solicit input from the public and interested parties on what elements to consider when designing a fair and effective consent-based siting process.

DOE issued an Invitation for Public Comment in December 2015 and held a kick-off meeting in January 2016 requesting feedback from communities, states, Tribal Nations, and other interested stakeholders. From March through July, DOE hosted a series of eight public meetings across the United States in order to engage with citizens at a national level and discuss the development of a consent-based approach to siting nuclear waste facilities. DOE is hosting a long-scheduled meeting tomorrow, September 15, to wrap up this process and discuss comments collected in our public meetings across the country. A report will subsequently be issued summarizing the results of those meetings.

By the end of the calendar year 2016, the Department will issue a number of documents, discussed below, for public comment and discussion. These include a draft consent-based siting process, as well as siting considerations for interim storage facilities and deep geologic repositories.

The Department's fiscal year 2017 Budget Request includes funding to help transition mutual learning and engagement activities for consent-based siting to the community level through a Funding Opportunity Announcement. Funds will enable communities to learn more about nuclear waste management and explore their potential roles in consent-based siting and the management of our Nation's nuclear waste. In total, our fiscal year 2017 Budget proposes \$39.4 million to support our efforts continuing to move forward with a consent-based approach to siting storage and disposal facilities, including \$25 million for grants to states, Tribal Nations, and local governments.

Consolidated Interim Storage

In parallel with developing a consent-based approach to siting, the Department is developing the concept of consolidated interim storage of commercial spent nuclear fuel. As outlined by the Administration's Strategy, consolidated storage will benefit the Nation regardless of how and when the waste is ultimately disposed.

Interim storage would encompass siting, though a consent-based process, a pilot interim storage facility and subsequently a consolidated interim storage facility with greater capacity and greater capabilities. A pilot facility would be focused on the near-term need of receiving spent fuel from the existing shutdown reactor sites around the country. A larger consolidated interim storage facility, potentially co-located with a pilot facility, would provide needed flexibility in the waste management system and allow for important capacity in implementing the Federal commitment to manage the Nation's spent nuclear fuel. These interim storage facilities, as part of an integrated waste management system, would perform important functions including:

- Allowing for the permanent removal of spent nuclear fuel from shutdown reactor sites;

- Allowing the Federal Government to begin meeting its contractual waste management commitments;
- Providing crucial flexibility for the overall nuclear waste management system, such as the ability to conduct thermal management activities and re-package spent nuclear fuel and high-level radioactive waste if necessary to prepare for permanent disposal, as well as the ability to regulate the future flow of waste shipments to a permanent disposal facility as circumstances require; and,
- Providing useful learning and experience, including opportunities to conduct R&D on the behavior of spent nuclear fuel and high-level radioactive waste over time.

DOE is currently in the process of developing generic design safety analyses for interim storage concepts for two primary reasons. The first is to inform potential host communities interested in learning more about how such a facility may fit into their future in terms of risks and benefits. This second is to develop the necessary regulatory strategies for moving the spent fuel from existing facilities, where in some cases it has been located for decades, and receiving it at new facilities in a safe and efficient manner.

Private Initiatives for Interim Storage

It should be noted that in order to construct an interim storage facility, DOE would need additional congressional authorization. However, in parallel with DOE's efforts to develop DOE-constructed and -operated facility concepts, we have seen the emergence of private initiatives that may provide interim storage services and potentially accelerate the schedule to remove spent fuel from the shutdown reactor sites.

These initiatives present a novel approach that is distinctly different from DOE's consent-based siting approach, as they essentially already include an aspect of community, state, and tribal consent. DOE is encouraged by the opportunities presented by these private initiatives, and we are preparing to seek public input on how a privately-owned storage facility could fit into the overall integrated waste management system. DOE will issue a Request for Information within the coming weeks.

Ongoing Efforts Towards Permanent Disposal

Moving forward with developing a consolidated interim storage concept does not mean we are putting on hold efforts to find a permanent disposal solution for nuclear waste. The Department continues to work to better understand different methods and geologies that can effectively isolate spent nuclear fuel and high-level waste from the biosphere for thousands of years into the future.

We are conducting analyses, as well as lab and field tests, including collaborations with international partners, to evaluate three main rock types for geologic disposal: crystalline, clay/shale, and salt. This information is essential to starting a meaningful dialogue with any community, state, or Tribe that is interested in learning about hosting a waste disposal facility. As with interim storage concepts, communities should have the most up-to-date information on waste disposal facility risks and benefits to allow them to make an informed decision on whether they wish to play a role in hosting such a facility.

DOE is also pursuing our planned deep borehole field test to advance the science and engineering knowledge and determine the feasibility of using the deep borehole approach for the possible disposal of smaller, DOE managed-waste as an alternative to mined geologic repositories.

Our earlier effort to begin the deep borehole project in January met with deep community concern after the contract was awarded, as local governments felt they were not sufficiently part of the procurement process. While this activity is a non-radioactive science project, the initial mistrust led to a general fear and suspicion that the Federal Government would force the community to accept waste at some point in the future. We recognized that a "reset" was in order to form the bonds of partnership from the onset and to ensure any community, state, or Tribe who played a role in the field test would be an important and valued partner.

As a result, the Department issued a new solicitation in August of this year that now includes a phased approach and allows for making more than one award. This will allow the best quality proposal to continue through community outreach and support and permitting approval before the more technically challenging design, testing, and drilling phases are started by the most promising contractor team. The results and data from this project, if the borehole disposal concept is proven feasible, will be essential to inform a yet-to-be-determined, future community on what it would take to host such a waste facility.

This improved approach is well underway, and we have recently received Letters of Intent to Submit Proposals that indicate there is continued strong interest. Full

proposals are due October 21st with plans to select one or more of those applicants early in 2017.

Defense Waste Repository

Consistent with the March 2015 Presidential determination that a defense-only repository is required, DOE is also developing plans for a defense waste repository. As I laid out in March of 2015, there are many advantages to pursuing defense and civilian waste on separate, parallel paths.

Unlike commercial spent fuel, which has an inventory that continues to grow, the United States is no longer generating defense high-level waste associated with weapons production, and the inventory is essentially finite and known. Some defense waste is also less radioactive, cooler, and easier to handle than commercial spent fuel, and a defense repository could therefore have a simpler design and present fewer licensing and transportation challenges. In addition, defense high-level waste streams are heterogeneous, existing in many different waste forms, which could allow for different disposal pathways. A majority of the inventory of defense high-level waste has been or will be vitrified, which means that it could be disposed in a separate repository with a simpler design.

A defense high-level waste repository could be selected, licensed, and built sooner than if it were disposed of in a common repository with civilian waste. This could potentially reduce ongoing storage, treatment, and management costs for defense waste currently stored at DOE facilities. Finally, successful development of a defense-waste-only repository could play an important role in a broader nuclear waste strategy by providing important experience in the design, siting, licensing, and development of the facility that could be applied to the development of a future repository for commercial spent fuel.

A repository for disposal of defense high-level waste allows greater flexibility in the selection of a site—and greater flexibility can help to keep costs down. Over the last year and a half, we have begun early planning to identify various activities that need to be performed to evaluate and design a separate repository for defense waste. Although these plans are preliminary, they begin to describe the different components—including technical, regulatory, risk management, cost and schedule considerations—that must come together to build a viable program, all within the framework of a consent-based siting process.

Fiscal year 2017 Budget to Continue Progress on Nuclear Waste Strategy

Overall, our budget proposes \$76.3 million for integrated waste management system activities, a \$53.8 million increase from fiscal year 2016, to work towards waste storage and disposal solutions, in addition to \$74.3 million for Used Nuclear Fuel Disposition R&D, to make progress on the needed research for transportation, storage and disposal. This budget will carry forward our consent-based siting, consolidated interim storage, and disposal activities in fiscal 2017 to move us toward a solution for managing the Nation's nuclear waste and avoid leaving the burden to future generations.

CONCLUSION

In conclusion, I appreciate the opportunity to discuss how nuclear energy is a vital component of the U.S. clean energy strategy. The Administration looks forward to working with the Subcommittee and other Members of Congress to ensure that our Nation can continue to benefit from the significant contributions of nuclear power to our energy needs and efforts to mitigate climate change.

The Department of Energy's programs continue to push to achieve these goals by advancing reactor technologies, developing used fuel management technologies and approaches, and supporting a world-class nuclear energy research infrastructure.

Chairman Alexander, Ranking Member Feinstein, and members of the Subcommittee, thank you for inviting me to discuss this important topic and the work that Department is currently doing. I will be happy to answer any questions you may have.

Senator ALEXANDER. Thanks, Mr. Secretary.
We'll now go to a round of 5-minute questions.

THE FUTURE OF NUCLEAR POWER

Mr. Secretary, you—as you know, I've been critical of the Administration's, what I believe to be, obsession with giant wind turbines and the continued subsidy of them. But, I would be—I want to

compliment you, and your predecessor, too, for continuing to be an advocate for the importance of nuclear power as a part of our energy future. And if it's true that, within 20 years—2038—48 reactors will be 60 years old, representing 40 percent of the nuclear generating capacity in the United States, we could lose half our reactors if the existing reactors can't be extended from 60 to 80 years, and these reactors close.

Now, if nuclear reactors produce 60 percent of our carbon-free emissions, and we lose 40 percent of that, it's a significant blow to the effort to reduce carbon emissions. Don't you see a real disconnect in the public discussion between those who see the urgency of climate change but who don't see nuclear as an important part of the solution?

Secretary MONIZ. Well, again, it certainly is a fact that nuclear power has been our largest carbon-free source. And I certainly think that having a strong, robust nuclear energy sector will be an important part of a highly decarbonized electricity sector by mid-century. So yes, I think it's very, very important.

Secondly, I agree with you, by the way, that—well, it's a question of arithmetic, basically—with 60 years lifetime, the major wave of retirement starts just around 2030, and I would use that to suggest that, when you look at the planning times for utilities, for investors, for large capital outlays, that means that we don't have a lot of time to have both the technology base, but also the kind of clear signals, in terms of support for nuclear power, resolving the nuclear waste issues, so that, in these next 5 years or so, those capital planning activities can really weave nuclear energy into that planning.

NUCLEAR WASTE STORAGE

Senator ALEXANDER. You were a member of the President's Blue Ribbon Commission on America's Nuclear Future, and you've testified about that. Let me go to Senator Feinstein's comments and some of your testimony.

You said that for consolidated storage to be of the greatest value to the waste management system, the current rigid legislative restriction that prevents a storage facility developed under the Nuclear Waste Policy Act from operating significantly earlier than a repository should be eliminated.

Now, the way I read those remarks and other comments you've made is this, that you support the idea that we should move on several tracks at the same time. And if one gets stalled, that doesn't mean we should stop the other two or three tracks. We should just keep pushing ahead and hope that one or more of those tracks succeeds. Am I correct about that?

Secretary MONIZ. Absolutely. And, in fact, the interim storage facility, in my view—facilities—always should have been part of an integrated waste management system, providing much greater flexibility and allowing us, again, also to avoid the liability that we have. And we're paying billions of dollars already by not moving spent fuel.

Senator ALEXANDER. Well, Senator Feinstein and I have been working for 5 years on this, and we were doing a pretty good job of reconciling Senators who have fundamentally different points of

view on nuclear power in some ways, but not on nuclear storage, not on the need for, the solution to it. And I thought it was a particularly boneheaded move by the nuclear industry to kind of jerk the rug out from under that effort by moving away from the idea that, if we have a chance to go for a short-term repository or a long-term repository or a private storage option or a defense option or Yucca Mountain, that we ought to push on all of those paths.

At present, Senator Feinstein and I have a different opinion on Yucca Mountain, but that doesn't keep us from agreeing that we should push ahead with something. And just because we're stalled on one aspect of storage, I think people who believe that if we stop one, we should stop all—are as misinformed, I think, as those who believe that climate change is urgent, but we don't need nuclear power to help solve the problem.

Senator——

Secretary MONIZ. May I——

Senator ALEXANDER. Yes, sir.

Secretary MONIZ [continuing]. Just comment on that? That I certainly agree with you. I would observe that, in particular, for the utilities operating nuclear power plants, if you look at their specific interests, the interest is to have the fuel moved away, whether it's to a storage facility, a repository immediately, or not. So, I think that this statement that we need to be sending the signals very soon about how we're going to meet the zero carbon generation in the 2030-and-beyond period includes this issue of providing the signal that, yes, you build a nuclear power plant, the government will move the spent fuel away, whether it's to a private or a public——

Senator ALEXANDER. We have significant bipartisan support in the Senate for moving on several tracks at the same time and with the hope that sometime that one or more of those will get there first.

Senator Feinstein.

Senator FEINSTEIN. Thanks, Mr. Chairman.

And I think you said it like it is.

Mr. Secretary, I'd like to call your attention page 11. There are two paragraphs I wanted to speak to you about. But, you know, it——

Secretary MONIZ. Excuse me, Senator Feinstein. Of my testimony?

Senator FEINSTEIN. Of your testimony.

Secretary MONIZ. Yes. Okay.

Senator FEINSTEIN. The consolidated interim storage part of it. To me, this is the key. You know, I think Southern California Edison has in the vicinity of 3300 rods in spent-fuel pools right at the facility, and no place to put them. And so, they sit there and—they've got 6 million people right around them. And they've had the same—they have big security. But, that isn't the answer. The answer is getting the stuff secured.

You state what interim storage would encompass through the consent-based process. And there's no question that it has to be consent-based, and there's no question that I think consent-based will work, because there are places and States that would like to participate in this.

The question comes, Do you have the ability just to do it? Your final paragraph here, which, "DOE is currently in the process of developing generic design safety analyses for interim storage concepts for two primary reasons, to inform potential host communities about how such a facility may fit into their future, in terms of risks and benefits; the second is to develop the necessary regulatory strategies for moving the spent fuel from existing facilities."

Now, this kind of endorses what the Chairman and I were just saying. The question that I have is, Can you just go ahead with it, or do you need legislation?

Secretary MONIZ. So, certainly, again, my understanding is that, for a government-operated facility, we would need congressional authorization to do that. However, our general counsel advises that, for a private storage facility, we have the authority, although it's not explicitly spelled out in statute, but language that has been put forward, I think, acknowledges that authority. I think that acknowledging that authority from the Congress is very important for confidence, I think, also of the applicant. So I think we're on the same page on that.

Senator FEINSTEIN. Okay. So, would you be prepared to move ahead on your own?

Secretary MONIZ. Well, I think if the Congress is supporting us to do that, yes. As I said, we are in a process of gathering information. We could move forward. There is some language right now about moving forward on setting up the contracting bases, which we could certainly do with the funding—\$10 million, I think, is proposed. And then, if we wanted to try to move that rapidly on the timescale that some of the interested parties are talking about, in fact, we would want to start doing some additional activity, particularly on the transportation of the spent-fuel side. That would require some additional funds. But, there's a lot that we could do to move forward.

Senator FEINSTEIN. Let me ask you. I think we're all agreed it should be consent-based. I mean, the problem with Yucca is, nobody in Nevada wants to move ahead with it. That's a problem. What would you advise? That you go ahead and develop the consent? Obviously, it's—

Secretary MONIZ. Yes. Well, so we want to go through this process. We want to provide—we want to be able to provide some support for interested communities so that they can work through the issues, make sure there's a lot of public confidence in this. Now, of course—again, there's public and there's private, both. On the private side, in a certain sense, going through the application to the NRC, which one group has already initiated that process, that is, in some sense, already suggesting a certain level of consent there. But, I think it's very important that we learn the lessons, not only of the past—1980s—but actually some also more recent events in which we've got to do the upfront work, in terms of working with the communities and the States and making sure we're all aligned in the interest. And certainly, I would be prepared to accelerate that process even more than we are currently doing.

Senator FEINSTEIN. Yes. Is that process set to go, pretty much, now?

Secretary MONIZ. In terms of—yes—in terms of getting—for example, the consent-based meeting—the summary meeting of that will be tomorrow, as I mentioned, following eight regional meetings. Then we will consolidate the input from the meetings tomorrow into a consent-based siting plan that we would like to issue later this year.

Senator FEINSTEIN. Okay. And the consent would be the Governor of the State, how would that part work?

Secretary MONIZ. Well, I think there's no—

Senator FEINSTEIN. Because that's important. That's where it all happens.

Secretary MONIZ. Sure, there's no specific rule. But, if they go back to the Blue Ribbon Commission, it was pointed out that, fundamentally, at the community, at the State, and at the Federal level, we have to be aligned to not get bad surprises later on.

Senator FEINSTEIN. Thank you.

Secretary MONIZ. Yes.

Senator FEINSTEIN. Good work.

Secretary MONIZ. Yes.

Senator FEINSTEIN. Thank you, Mr. Chair.

Senator ALEXANDER. Senator Udall.

REGIONAL INNOVATION PARTNERSHIPS

Senator UDALL. Thank you, Mr. Chairman.

Thank you, Secretary Moniz, for being here, and for your excellent testimony on all ends of the nuclear issue.

I wanted to talk a little bit about the visit you had to New Mexico. Senator Heinrich and I sent you a letter, I think today, expressing thanks for your participation in the Southwest Regional Energy Innovation Forum hosted by the University of New Mexico this July. The successful forum brought together as you know, 140 university, National Lab, government, and industry participants to discuss the critical issue of clean energy technologies at the regional level and at the national level. And nuclear energy played a key role in those discussions.

I'd like to reiterate our strong desire to see New Mexico, with our labs and universities, play a key role in the Department of Energy's Mission Innovation Initiative. New Mexico can be a hub for the Four Corners region to explore revolutionary materials necessary to transform energy technologies in markets, not only in nuclear energy, but photovoltaics, fuel cells, novel materials essential for clean energy growth. Lots going on in the Southwest. And I strongly believe that New Mexico can bring together cutting-edge industries, university researchers, local and State governments, and national energy labs to address regional and national energy challenges.

Can you talk about the progress we're making towards regional innovation centers and how New Mexico can play a greater role in mission innovation in the future, given DOE's assets in the State?

Secretary MONIZ. Well, thank you, Senator Udall. And thank you for coming to Lab Day yesterday, as well.

Senator UDALL. Thank you.

Secretary MONIZ. First of all, the regional meeting in New Mexico, in Albuquerque, was really terrific. It had a focus completely

on materials, for hydrogen, for batteries, for nuclear. So, that was terrific.

We just had our 13th regional meeting, on Monday, in Morgantown. We've now covered just about all parts of the country. The enthusiasm for the regional innovation partnerships has been absolutely uniform. I have to say, if one set of institutions has been particularly excited, it's been our research universities. Like UNM, in the case of hosting that meeting.

So, we are very, very eager to move forward with this. We did make a proposal in the budget. We hope that will be reconsidered in the final discussions of the budget, because this would be a new start. So, I think we have to wait for some form of bus at the end of the CR. We are putting together summary documents of what we learned in these 13 meetings, which included Tennessee and California and New Mexico, all three of you. We would like to then, now, solicit ideas about how one promotes regional innovation. Because I think this idea has really got a lot of very, very positive attention. That was one of 13 examples of that.

Senator UDALL. Yes. No, thank you for——

Secretary MONIZ. And New Mexico—that part of the questions—again, I—obviously, I can't prejudge the competition and——

Senator UDALL. Right.

Secretary MONIZ [continuing]. How people would organize non-profits. But, certainly there's no question, New Mexico has, obviously, some major innovation assets—universities, labs—and could very well organize one of those teams.

Senator UDALL. Yes. Great. Thank you very much.

WASTE ISOLATION PILOT PLANT

And let me take just a minute to stress that we're eager to see that the Waste Isolation Plant be reopened, and that be done with worker and community safety as a top priority. And I know that you've talked about that many times.

On that topic, I want to ensure that inspections by the Mine Safety and Health Administration will continue at WIPP at least four times per year, as required by law, and that all issues are remedied as quickly as possible. Unfortunately, those inspections had fallen off, as you know, at WIPP prior to the accident that caused——

Secretary MONIZ. Right.

Senator UDALL [continuing]. The radiation release. Will you give DOE's commitment on this to continue——

Secretary MONIZ. Absolutely. And, in fact, frankly, I think we will be reopening with, certainly, I would say, upgraded mine operations. There was a real issue, in terms of the bolting, for example. That's been gone after now aggressively. And, frankly, we are helped now by getting some more air down below, which is going to allow greater work effort down there to complete—for example, the mine inspector particularly focused on those roof bolting issues, and those have been—the pace of addressing that has been picked up dramatically.

Senator UDALL. Yes.

CLEANUP AT LOS ALAMOS NATIONAL LABORATORY

Mr. Chairman, I only have one more quick question. I know I'm running out of time here. Is that okay?

On the topic of nuclear waste cleanup, I believe it's important for the Department of Energy to prepare a lifecycle cost estimate cleanup at Los Alamos National Laboratory. Each year, we need to make a case to our Chairman and Ranking Member on why we believe Los Alamos needs funds for cleanup. And I believe such an estimate would be helpful to demonstrate where those funds are needed and can be used. Can I get your commitment to work with us on that?

Secretary MONIZ. Yes, absolutely, Senator. And we're well along on that. We have a preliminary draft that, in fact, was shared with some of the local citizens, but—it's a preliminary draft, so we still have a process to go through. But, we hope to have that, certainly this year.

Senator UDALL. Great. Thank you very much.

Secretary MONIZ. And we'll work with you on that.

Senator UDALL. Yes. Thank you very much.

Thank you, Mr. Chairman.

SAFELY EXTENDING LICENSES FROM 60 TO 80 YEARS

Senator ALEXANDER. We'll have one more round of questions for the Secretary, if he can spare that time, and then we'll go to our next panel.

Mr. Secretary, I think I'm about right in this. It—a new nuclear reactor might cost \$10- or \$12 billion and might take 8 years or so to build. I guess it would depend on factors. Nobody's quite sure. But, they're very expensive and large projects to do correctly. And while we're waiting to see whether the California experiment in renewable energy takes it down the road of Germany, or not, and while we're waiting to see whether these 50 companies who are working in entrepreneurial efforts in advanced reactors and other things, over the next 20 years we could lose half of our existing reactors if their licenses can't be extended from 60 to 80 years. Now, in practical terms, that means we can get another 20 years of cheaper, reliable, carbon-free electricity that would represent about a quarter, from these reactors that I'm talking about, of all of our carbon-free energy.

What are you doing—you've mentioned some things, but what are the prospects for safely extending the licenses of, say, half of the 99 reactors we have today for another 20 years, and giving us that 20 years of cheaper, reliable, carbon-free electricity?

Secretary MONIZ. Well, clearly, I think I cannot judge the outcome of the NRC evaluations, but let me say, as was mentioned earlier, we are certainly supporting work to support those applications—materials work, controls issues, et cetera. And, by the way, I think CASL can be a big help in this. I should add perhaps, as well, that, since I had the pleasure of being the chairman of the CASL board for its first 2 years, that, right from the beginning, another important issue, which is quite relevant to this, is that, right from the beginning, CASL leadership engaged the NRC to make sure the NRC could understand these tool developments as they

were happening so that they could be integrated into their licensing. And when it comes to the 80 years, I think that's going to be very, very important.

So, we're working that. We work with NRC also directly, in terms of the various criteria, whether it's for the 20-year extension or for things like advanced reactors, how to develop the criteria for advanced reactor licensing. So, we're pushing on that. But, I think now some companies have come forward. They're planning to go ahead with the additional 20-year application with the NRC, and I think that's going to be a process that we will support as best we can.

Senator ALEXANDER. Well, for those companies and for the country, I think—speaking as one Senator, I want to do whatever I can to create an environment where a utility can make that decision, if it's possible to extend the license and do it safely.

Secretary MONIZ. Safely, right.

Senator ALEXANDER. I think it's in the best interests—

Secretary MONIZ. Right.

Senator ALEXANDER [continuing]. Of the country, for many, many reasons.

ADVANCED NUCLEAR REACTORS

My last question is—has to do with those 50 entrepreneurs you talked about. You released a draft Vision for Advanced Nuclear Power. Do you support the goal stated in one of your reports to have two advanced reactors licensed by the early 2030s? And why do you suppose there's this flurry of entrepreneurial activity at a time when there are clearly obstacles to building new reactors? The low cost of natural gas, excessive regulation, the negative pricing from wind power—despite that, you see all this entrepreneurial activity. What's the source of that?

Secretary MONIZ. Well I'm not sure I know. But, it certainly is extremely interesting. I think it is driven, to a large extent, by the expectation as evolves from any serious scenario about meeting our climate goals, that the electricity sector is the first sector to, essentially, totally decarbonize. And in that future, then—and I am very bullish, as you know, on both wind and solar. But, they are variable technologies. Now, advances in storage—lower-cost storage, would be very important. But, I still have to say that I find, you know, the nuclear power zero-carbon baseload possibilities to be very important.

In addition, some of those entrepreneurs are looking at their—the technologies, not just for electricity, but for other applications, as well. And some of those technologies are, in fact, potentially well suited to producing low—zero-carbon heat, for example, to do hybrid technologies with renewables, a program that actually we are working on, as well, right now.

So, I think they're seeing a lot of possibilities and seeing new ideas. The fact is, you know, we have not, I think, had—there was a long period of, I would say, not a terrible amount of innovation in this arena. Obviously, given the long hiatus in building plants, one can understand that. But, I think the confluence of the low-carbon future, the importance of that, specifically in the power sector, and the fact that so many new tools and technologies are available

to apply in this space that haven't been applied for a long time, that I think the entrepreneurial community is seeing that coming together.

We do have a challenge. As I said earlier, we feel a focus area for us is to try to build up the accessibility to our energy infrastructure—to our nuclear infrastructure for these companies. But, I have to concede that there are some areas in which we just don't have the infrastructure, in fact, and we know that some of those entrepreneurs are going to other countries to find, for example, fast neutron spectrum.

Senator ALEXANDER. Thank you.

ENERGY STORAGE

As to the storage, I hope we do make great advances in storage. My suspicion is that the major source of electricity that will benefit from improved storage will be nuclear, because of the size of the nuclear generating capacity and you can't turn a nuclear reactor up and down, and it produces a lot of electricity at night that's not needed. So, my guess would be that if we improve our storage capacities, that our reactors may be able to take more advantage of that than any other form of electricity.

Secretary MONIZ. It depends on the mix. And, obviously, in France, for example, where they had so much nuclear—75 percent—they had to have a third or 40 percent of their fleet with ramping capability, in fact.

Senator ALEXANDER. Senator Feinstein.

Senator FEINSTEIN. Thank you very much, Mr. Chairman.

REACTOR LICENSE EXTENSIONS

I believe we have 16 new nuclear plants, so far, that have shut down, and another 7 coming in the next few years. That's for a variety of reasons. Some, like plants in Illinois and Wisconsin, can't compete with natural gas. Others, like Vermont Yankee, are closing after sustained local opposition. Still others have had equipment or structural issues, like San Onofre and Crystal River. Given these private-sector, market-driven decisions, why would DOE invest by extending operating licenses from 60 to 80 years?

Secretary MONIZ. Well, of course, for those plants, unless there were dramatic retrofits needed, a lot of it's capital sunk costs. And capital costs, of course, drive it, so they can have relatively low, at least, marginal operating costs.

Secondly, for the long term, there's no doubt that the shale gas revolution has been a tremendous economic boom—boon to the country, but also an environmental one, from the point of view of—it accounts for about 60 percent of our lower CO₂ emissions by substituting for coal so dramatically. However, as I said earlier, if we look forward to mid-century and beyond, we're talking about really low carbon in the electricity sector, like decarbonized, and then natural gas will also have emissions. As long as it's substituting for coal, it lowers emissions; but, if it substitutes for nuclear, it's raising emissions. And so, I think that if you're a utility executive and you're looking forward to the low-carbon future, the natural gas production still looks very, very strong. And EIA (Energy Information Administration) still projects very modest prices for natural

gas for a long time. But, there is a vulnerability, a risk to fuel costs, which traditionally was the issue with natural gas. So, in terms of a portfolio and going to zero carbon, that's why we would see nuclear as an important contributor along with renewables.

Senator FEINSTEIN. Is it prudent, with all of the stresses on plant and materials—

Secretary MONIZ. Well, that's what I say. I mean, that—

Senator FEINSTEIN [continuing]. To go from 60 to 80 years?

Secretary MONIZ. That's what I'm saying, where I'm not going to judge the outcome.

Senator FEINSTEIN. Okay.

Secretary MONIZ. So, all we are doing is, we are supporting some of the research, for example, that will be needed to make that judgment at the NRC—materials—the materials issues, for example, with time, with more radiation flux and the like. So—yes, so—no, so I don't judge the result. But, I do think it's our responsibility to develop the technology and the tools to help that informed decision.

FUSION ENERGY

Senator FEINSTEIN. Could you just talk a little bit about fusion energy? ITER—as you know, we had concerns about funding ITER. And you won one from us, right? So—and small companies are making progress with innovative approaches, with burning plasmas and other things. Where is ITER? And what is your position today, so we can be aware?

Secretary MONIZ. The ITER situation is what we summarized in our report to the Congress. Basically, our statement was that there's no doubt that the new leadership of ITER—Mr. Bigot—has made tremendous strides in pulling together this project. But, we also said that there was a long way to go. And we put down some, I think, pretty stringent conditions that we are going to insist upon being met to make what we felt was that the right time for the decision, given what's happened with ITER, is probably—I think we said at the end of 2017, to influence the next year—fiscal year's budget. So, we're probably a year away from really having, I think, the information that would come back, administration and Congress, to make a decision.

Senator FEINSTEIN. So, you won't ask for any additional money.

Secretary MONIZ. I didn't say that. Well, whoever it is, next year—a reminder: Almost all the funding to ITER—in fact, by congressional direction, all the funding of last year—was to American institutions and companies building equipment for ITER. So, it was not like just sending 100-and-some-million dollars to Cadarache. The 100-million-dollar scale was for building things here. And so, we said, “Look, we have a commitment to, in the international arena, at least to first plasma, which is the middle of the next decade.” Ignition would be in the 2030s. So, we said, “Look, we have a responsibility to deliver some equipment that we manufacture to first plasma. There's also, however, more work that needs to be done”—I give Bigot a lot of credit for what he's done, in terms of shaping that up as a project. But, there's still a ways to go. And, frankly, the countries have to cooperate in making this really go as

an integrated project and not as, “Well, I’ll do my thing here, and you do your thing there.”

So, that’s where we are. And so, we are deeply engaged. I think we’ve brought more discipline to this. And the real time to judge this will be just over a year from now.

Senator FEINSTEIN. Thanks, Mr. Secretary.

Secretary MONIZ. Yes.

Senator FEINSTEIN. Thanks, Mr. Chairman.

Senator ALEXANDER. Thank you, Senator Feinstein.

Senator—Secretary Moniz, thank you for——

Secretary MONIZ. You keep promoting me to——

Senator ALEXANDER. I know. Well——

Secretary MONIZ [continuing]. To Senator.

[Laughter.]

Senator ALEXANDER. Senator Collins, Secretary Moniz is about to leave. Would you like to ask questions before he—all right.

Secretary MONIZ. We had an interaction earlier today——

Senator ALEXANDER. Mr. Secretary——

Secretary MONIZ [continuing]. On an offshore wind. Your favorite subject.

[Laughter.]

Senator ALEXANDER. No, no. We took care of it, Senator Collins.

[Laughter.]

Senator ALEXANDER. I don’t know how many other times you’ll appear before our subcommittee. Maybe this is the last. But, I genuinely appreciate the way you’ve worked with us in Congress from the day you arrived, being accessible and letting us know in advance of things, whether we liked those things or not, and the fact that you had a lot of experience in the Department where you went, and you knew the subject cold—has made you a very effective member of the President’s Cabinet. So, I thank you for that service and look forward to continuing to work with you during the rest of the year.

Secretary MONIZ. Thank you very much. And I appreciate the opportunity to have worked with you, including on the issues that Senator Feinstein described earlier. But, working not only in a bipartisan way, but in a nonpartisan way.

Senator ALEXANDER. Well, we like to work that way.

We will now excuse Secretary Moniz and invite the witnesses for our second panel to be seated at the witness table, and then I will introduce them.

NONDEPARTMENTAL WITNESSES

Senator ALEXANDER. Our second panel includes someone very familiar to all of us, Senator Judd Gregg, of New Hampshire, a flinty individual who served in this body with great distinction, watching the budget and working on education and healthcare and other matters. We are delighted to see him and welcome him back. He is the Leadership Chair of Nuclear Matters. We welcome, again, Jay Faison, whom many of us know, Founder and CEO of The ClearPath Foundation.

We have your testimony, and have read it. If you could summarize it in 5 minutes or so and give us a chance to have a conversation with you, we would appreciate it.

Senator Gregg, we'll start with you.

STATEMENT OF HON. JUDD GREGG, FORMER U.S. SENATOR FROM NEW HAMPSHIRE

Mr. GREGG. Well, first off, let me say what a great honor it is to be here to address this Senate committee, of which I had an opportunity to participate. And obviously, it's a great honor to be here with folks that I consider friends. Thank you for having me.

PREMATURE CLOSURE OF PLANTS

Actually, so much of what I was going to say has already been said, and said better than I could say it, by the Chairman, by Senator Whitehouse, by the Secretary. I'm not speaking about waste issues, so I haven't necessarily gotten into the issues of Senator Feinstein, but, on the issue of premature closure of plants, the Chairman has said, Why would we do it? The Secretary has said, Why would we do it? And Senator Whitehouse has said, Why would we do it? And that's what our group is about, asking, Why would we do something like that? Because it makes no sense, from the standpoint of policy.

The Nuclear Matters Coalition essentially takes the position that if a plant has useful life, it should not be closed, that you shouldn't have premature closure, that there are approximately five plants now that have been closed prematurely, that still had useful life, that there are eight more that are at significant risk of being closed, that still have useful life, and then probably another five to ten that are likely to fall into that category.

As has been suggested here rather effectively and forthrightly, obviously nuclear power plays a very positive role in our electrical production in this country. It is noncarbon-based. Twenty percent of the baseload is nuclear, as was mentioned, and 60 percent of the noncarbon-based energy in this country is nuclear. Every time you close one of these plants, it's the practical effect of putting a million cars on the road. And so, it makes no sense, from the standpoint of environmental protection, especially.

It also makes no sense from the standpoint of reliability. Those of us who suffered through the polar vortex of 2014 know that we came very close to a major blackout in the Northeast and the Midwest, which would have had devastating economic effect. The only thing that saved us from that was our nuclear plants, because they function 24/7, and they are not affected by that type of weather event.

In addition, of course, nuclear brings big-time jobs and economic benefit to the communities in which it's located, and it completes the diversity picture of our energy supply. As we move towards gas replacing coal, as was mentioned by the Secretary, we don't want to get in the position of all the eggs in one basket. Nuclear being 20 percent of our baseload really is an important part of making sure that we don't have an all-eggs-in-one-basket approach.

These plants that are being closed prematurely are being closed for economic reasons primarily, and it's because nuclear is at a significant disadvantage in the present culture of structured markets. Essentially, these markets end up with spot pricing of energy. And in a spot-pricing situation, nuclear can't compete as effectively as the other types of energy, especially gas, because the capital costs of building the plant are not really factored in to the pricing of the product or, alternatively, it's competing against energy which is highly subsidized. And nuclear isn't highly subsidized.

How do you address this? Well, our view is, you address it, first, by making people aware of how important nuclear is, and, second, by giving nuclear some sort of support in the area of recognizing that it is carbon-free and that it is reliable and it is part of the diversity mix. This probably is going to be done on a State-by-State basis. It's being done in New York now. It's being moved forward, hopefully, in Illinois, as different States realize the importance of their nuclear mix in maintaining and reducing their carbon, and in maintaining their reliability.

So, that's our theme. We are an advocacy group, in the sense that we've been out proselytizing this approach across the country. We aren't involved in the other areas of nuclear issues directly, other than to be very supportive of nuclear power, as I personally am.

I thank the Chairman for his time, and the Ranking Member for her time, and obviously, the Senator from Maine.

[The statement follows:]

PREPARED STATEMENT OF HON. JUDD GREGG

Good afternoon, Chairman Alexander, Ranking Member Feinstein and Members of the Subcommittee. Thank you for the opportunity to appear before you as the Chairman of Nuclear Matters to talk about the role nuclear energy will play in our clean energy future.

Nuclear Matters is a coalition of organizations that recognizes the value of America's nuclear energy plants, educates the public on the clear benefits of nuclear energy, and explores possible policy solutions to preserve this essential part of the Nation's energy infrastructure.

Our Nation's nuclear power plants are vital national assets that provide reliable, carbon-free electricity to tens of millions of households and businesses around the country.

Despite their value, a combination of factors—including low natural gas prices and market rules that fail to recognize this value and subsidies that depress electricity prices—have caused otherwise exemplary performing nuclear plants to close and put the future of others in jeopardy.

The implications of these closures—both today and in the future—will have staggering impacts on the country's economy and its goals to decarbonize the electricity sector.

With Watts Bar II coming online in Tennessee, the United States has nearly 100 nuclear power plants, which generate 20 percent of our electricity and 62 percent of the Nation's carbon-free electricity. Nuclear plants are the Nation's most reliable source of electricity, operating nonstop for 18 to 24 months before they have to re-fuel.

Nuclear energy has a distinct set of attributes, generating vast amounts of electricity, emission-free, around the clock. No other electricity source can match that. In a carbon-constrained world, with an economy and a way of life that depend on reliable electricity, we cannot afford to take nuclear energy for granted.

For most parts of the country, meeting state and national carbon reduction goals, including the Environmental Protection Agency's Clean Power Plan, will be compromised without existing nuclear power plants. Bear in mind that the carbon-reduction targets for the Clean Power Plan reflect an energy supply that includes a large contribution of electricity from carbon-free nuclear power plants. When nuclear plants shut down, most of the baseload generation that fills the gap usually comes from fossil-fueled electricity sources, with a resultant rise in carbon emissions. This was a measurable result in the New England region after the Vermont Yankee nuclear plant closed in 2014.

Renewables like wind and solar represent a growing share of our electricity supply, and it is vital that we continue to develop them. However, these sources are still a small fraction of our total generation and renewables are not equally viable in all parts of the country. States need the flexibility to keep existing nuclear plants online.

In 2015, U.S. nuclear power plants avoided 564 million metric tons of carbon dioxide. Without the 99 nuclear power plants that operate in 30 states, carbon emissions from the U.S. electric sector would be approximately 25 percent higher. After Vermont Yankee closed carbon emissions in New England increased by almost 1.5 million tons. That's a 5 percent increase in emissions at a time when we desperately need to be going in the other direction.

In contrast, the Clean Energy Standard (CES) that New York recently approved assigns a value to nuclear energy facilities based on their clean electricity output. The new policy could keep at-risk nuclear power plants operating, help the state meet its emission reduction goals and keep electricity rates predictable. Already, the prospect of beneficial changes resulting from the CES is helping to facilitate the sale of one nuclear plant that was under the threat of closure. I hope that policymakers from around the country are paying attention to New York's example.

The clean-air benefits of nuclear energy ought to be obvious. Their reliability ensures that we can maintain safe temperatures in our homes in the worst heat waves or the coldest winters. Their fuel doesn't freeze. It doesn't have to be delivered "just in time" as it is

used. They don't stop generating electricity when the sun doesn't shine or the wind doesn't blow.

Nuclear energy also provides substantial economic benefits. At the national level, they are significant. Each year, the average nuclear plant generates approximately \$470 million in economic output or value. This includes more than \$40 million in total labor income. These figures include both direct output and secondary effects. The direct output reflects the plant's annual electricity sales—approximately \$453 million.

At the local level, nuclear plants are often the economic anchors of their community employing 500–700 workers per plant. Shutting down safe, reliable nuclear plants because the markets haven't found a way to compensate their value unfortunately means that hundreds of people lose good-paying jobs, while local businesses lose customers. The closure of Vermont Yankee is a loss of 600 highly skilled jobs.

The average nuclear plant pays about \$16 million in state and local taxes annually. These tax dollars benefit schools, roads, and other state and local infrastructure. The average nuclear plant also pays Federal taxes of \$67 million annually.

The U.S. Department of Energy projects that demand for electricity in the United States will rise by 22 percent by 2040. That means our Nation will need new sources to provide electricity for our homes and continued economic growth.

As Congress considers its policies toward nuclear energy we encourage this committee and your colleagues to consider policies that recognize the benefits that nuclear energy provides and support regulations that streamline the regulatory process of permitting and license renewal, while still maintaining rigorous oversight.

On behalf of Nuclear Matters, I want to thank this committee for giving consideration to these important issues facing the industry.

We look forward to supporting Congress in its efforts to maintain nuclear as a valuable energy source for hard working Americans well into the future.

Senator Alexander: Thank you, Senator Gregg.
Mr. Faison.

STATEMENT OF JAY FAISON, FOUNDER AND CEO, THE CLEARPATH FOUNDATION

Mr. FAISON. First, I'd like to thank the Chairman, Ranking Member, and members of the committee for the chance to testify.

I come to this discussion as an entrepreneur, turned philanthropist, turned energy policy advocate. At ClearPath, we focus on accelerating conservative clean energy. We don't make any money at this, and so I hope I can contribute an independent perspective on nuclear energy policy.

ADVANCED NUCLEAR ENERGY DESIGN

Fifty years ago, when America was the major innovator in nuclear technology, we demonstrated many nuclear concepts—concepts beyond the light water reactors we have today. In recent years, American nuclear entrepreneurs have dusted off these alternative technologies and are refining them, designing reactors that most estimate will cost significantly less than the current reactors. There are now 40 to 50 companies working on advanced nuclear designs across America. These concepts have attributes that can provide services beyond those available from today's large light water reactors, including: many can be built in a factory to reduce construction costs; they can ramp up and down quickly, essential for a modern energy system; most of the concepts are walkaway safe, with passive safety features automatically halting a nuclear reaction if a malfunction occurs; some can recycle used fuel and therefore, potentially help deal with our nuclear waste problem.

While the prospect for advanced reactors is bright, our nuclear industry faces challenges abroad, where Russia and China are moving quickly to develop their own designs and export technology around the world. Domestically, our fleet is aging. A number of them may retire prematurely in the coming years, in part due to the market distortions caused by highly subsidized wind generation. Additionally, since the 1970s, only five new reactor construction projects have been started in the U.S., all of them within the last 5 years. This drastically reduces our ability to deliver new projects affordably, given the complexity of building a large new nuclear plant.

ELECTRICITY MIX

Despite these challenges, I believe that nuclear should be between 30 and 40 percent of our electricity mix if we're to maintain affordability and reliability while reducing emissions. 2040 is an aggressive, but doable, target for this goal. Doing so would require dozens of new reactors to be built to replace some of our aging light water reactors. Before those commercial projects, multiple projects for advanced reactors will need to be carried out in the 2020s to prove feasibility and economics for these technologies. Federal policy should embrace this goal to provide the support necessary to achieve it.

Given the large regulatory hurdles and the high initial cost for each technology, government can contribute in four areas:

REGULATORY ENVIRONMENT

First, we need a rational regulatory environment for advanced nuclear. Recent bills in the Senate and the House are good first steps, but need to be accompanied by the NRC aiding advancement of R&D in improved technologies.

TECHNOLOGY GOALS

Second, and building on the Secretary's testimony about the need for clear signals, DOE needs to work with industry to set ambitious technology goals. The DOE performs well when given a steady funding source and a target. While recent goals and initiatives like the Advanced Reactor Concepts Program are a good start, they won't go far enough. For example, one possible goal would be for DOE to support the demonstration of at least five different advanced reactor technologies by 2026 at \$65 to \$70 a megawatt hour. While ambitious, I believe this is achievable.

PRIVATE-SECTOR INNOVATION

Third, the government should work more closely with industry by complementing private-sector innovation. DOE and the Office of Science and Technology Policy should work closely with an advisory board of reactor designers, utilities, and other end users to identify research priorities and efficiently co-invest public and private capital to accelerate innovation efforts. The DOE and NRC should continue recent efforts in the spirit of the GAIN Initiative, enabling companies to develop their designs, removing regulatory roadblocks, creating and maintaining high-quality user facilities while solving these fundamental challenges.

ELIMINATING SILOS

Fourth, silos must be eliminated. Appropriators should work together with the DOE to consider how the budget can better enable crosscutting nuclear initiatives outside the standard funding framework. We should stop funding tools and start funding outcomes. DOE should be given the flexibility to work towards a goal, even when that goal spans multiple offices and lab jurisdictions. Oversight should be focused on whether or not the DOE is working towards its technology goals while recognizing that some ideas will fail.

In closing, America has an opportunity to continue to lead the global market for clean, affordable, reliable advanced reactors. Without a more focused government effort, we will be unable to sustain our nuclear industry and control nuclear proliferation. ClearPath and our advisors are eager to assist in realizing this opportunity.

Thank you.

[The statement follows:]

PREPARED STATEMENT OF JAY FAISON

I'd like to thank Chairman Alexander, Ranking Member Feinstein, and other members of the Subcommittee for this opportunity to testify today. This subcommittee has continued to be a staunch supporter of nuclear innovation through initiatives such as the Advanced Reactor Concepts Program and initiatives for Small Module Reactor (SMR) research. I come to this discussion as an entrepreneur-

turned-philanthropist-turned-energy policy advocate. After donating the money from the sale of my last company to create ClearPath Foundation, I developed a passion for better energy policy, and have been studying it with our expert policy team ever since. At ClearPath, we focus on accelerating conservative clean energy. We don't make any money at this, and so I hope that today I can contribute an independent perspective on nuclear energy policy.

Energy drives everything we do. Our businesses and households depend on reliable, affordable energy. And Americans increasingly expect cleaner energy sources to reduce environmental risks. However, as the saying goes, "What got us here, won't get us there."

We know how critical energy diversity is to reducing the risks of price spikes, supply shortages and natural disasters. We are now putting pressure on our energy system to modernize, and, while doing so, it is important that we maintain the diversity of our energy mix. Intermittent renewables such as wind and solar can be good additions to our energy supply. But unlike other energy sources, as their system penetration increases, costs rise rather than fall due to the burden of compensating for their intermittency. Greatly scaling up these intermittent resources requires expensive backup sources when the sun isn't shining or the wind isn't blowing. Germany has shown what happens: it's trying to both close its nuclear plants and dramatically increase solar and wind, a plan which has only raised electricity prices and increased reliance on inefficient lignite coal.

Nuclear remains our most reliable clean energy source. It is our clean energy workhorse, supplying almost 20 percent of our energy supply and more than 60 percent of our clean power. On average, the plants operate year-in, year-out at about 90 percent of their theoretical maximum (and 95 percent of the time during the extreme temperatures of winter and summer)—significantly higher than any other source of electricity. Fuel is a relatively small fraction of the cost of electricity produced by nuclear plants and is stored onsite. By comparison, fuel represents 80–90 percent of the cost of electricity from a gas-fired combined cycle plant, and gas supply can be interrupted during periods of extreme weather, when gas is diverted to homes and businesses.

A healthy nuclear industry is also vital to our national defense. Our preeminence in nuclear science and engineering allows us to lead globally on nuclear safety and nuclear weapons non-proliferation. Ceding that leadership to other countries is not in our national interest and could prove to be dangerous. A robust domestic nuclear energy infrastructure and supply chain is vital to maintain global leadership.

However, since the 1980s, only four new reactor construction projects have been started in the US, all of them in the last 5 years. This drastically reduces our ability to deliver new projects affordably, given the complexity of building a large new nuclear power plant. The supply chain and experience base for new construction has been decimated by years of inactivity.

This factor, coupled with unusually cheap natural gas, subsidized renewables, and a complicated regulatory system make building more large light-water nuclear plants a difficult proposition—at best. Like all of our infrastructure, our existing fleet is aging. A number of them may retire prematurely in the coming years, in part due to the market distortions caused by highly subsidized wind generation, outdated price controls in the wholesale markets, and the painfully slow pace of new transmission build-out. Most of today's reactors will operate for at least 60 years. But this decline places our entire energy infrastructure and national security at risk and will almost certainly result in increased carbon emissions.

Despite these challenges, I believe that nuclear should be between 30 and 40 percent of our electricity mix if we are to maintain price stability, affordability, and reliability while greatly reducing emissions.

2040 is an aggressive but achievable goal for this level of penetration. Doing so requires three categories of actions: (1) support our existing fleet of nuclear power plants by removing the distortive, non-market barriers and disincentives; (2) reduce bureaucracy to enable substantial investment in the construction of new nuclear power plants using proven light water technology; and (3) accelerate and remove the obstacles to research, development and commercial deployment of a new generation of advanced nuclear energy technologies. This testimony focuses on that third pillar, aggressively moving forward with advanced nuclear energy technologies.

Increasing the amount of nuclear energy made in America by 2040 would require dozens of new reactors to be built in the late 2020s and 30s to replace some of our aging light-water reactors, to meet additional demand growth, and to gain market share. The speed and scale of this build-up cannot be accomplished with today's technologies: Advanced reactors are the answer to increase nuclear penetration and to preserve this critical industry. Before committing to those commercial projects, industry will need to participate in multiple demonstrations of advanced— mostly

non-light water—reactors in the 2020s to prove out their feasibility and economics. Federal policy should embrace this goal and provide the support necessary to achieve it.

Forty to fifty years ago, when America was the world's innovator in the peaceful use of nuclear technology. We demonstrated many advanced nuclear power approaches beyond light water reactors. Recently, American nuclear entrepreneurs have dusted off, and begun to refine, these alternatives—designing reactors that most estimate will cost significantly less than the current leading reactor from Westinghouse. There are now 44 companies and organizations working on advanced nuclear designs across America.

These concepts, some many years in the making, have attributes and can provide services beyond those available from today's large light-water reactors, including:

- Many can be built on an assembly line and delivered to the site, reducing construction costs and delays.
- Many can ramp up and down quickly, which complements the intermittency of renewables and variations in demand.
- Many of the concepts have passive safety features automatically halting a nuclear reaction if a malfunction occurs.
- Many are expected to have far lower operating costs.
- Many can recycle used fuel, and therefore potentially help deal with our nuclear waste problem.
- Many operate at low pressure, requiring a fraction of the concrete and steel associated with current pressurized reactors, at tremendous cost-savings.
- All excite the new generation of engineers desperately needed to replace an aging workforce and breathe life into the industry as a whole.

Given the extraordinary regulatory and financial hurdles faced by the nuclear industry, government can contribute in four areas to enable private sector investment:

First, it must create a rational regulatory environment for advanced nuclear.

The Nuclear Regulatory Commission's (NRC) overly conservative regulatory approach could squelch advanced nuclear efforts even before they get off the ground. The Commission is focused on traditional light-water reactors and is not prepared to oversee new technologies in an efficient and effective manner. As a result, some of our nuclear entrepreneurs are moving their development and testing overseas to countries that are eager to embrace these innovative technologies. We chronicled one such promising company, ThorCon, and its decision to move offshore to Indonesia. Recent leadership changes in the NRC's Office of New Reactors is a major step in the right direction, and we applaud this progress. However, reluctance by line reviewers to embrace new concepts and technologies could still scuttle entrepreneurial efforts. NRC's mission needs to be clarified to explicitly encourage advanced reactor licensing.

Recent legislation in Senate Bill 2795 and House Bill 4979 represent a step in the right direction by developing a potential framework that is staged, risk-informed, and performance based. The proposed budget to begin developing this separate regulatory pathway inside the NRC is only \$5 million. We were pleased to see this money make it into the committee's markup earlier this year and hope the advanced licensing capacity at NRC continues its growth in the future.

Second, the government must provide a new framework that works with industry to set ambitious technology goals.

The Department of Energy's (DOE) continued support for SMR technology will help lay the groundwork for advanced reactor licensing. The DOE's recent draft goal of two advanced reactors licensed by 2030 as well as the Advanced Reactor Concepts (ARC) program to help achieve that goal have started us in this direction. Considering the need to demonstrate multiple technology pathways (as some will fail), we can surely do better than our current goal. Some advanced reactor developers are also planning construction for the mid-2020's, which is faster than the current 2030 licensing expectation. While a step in the right direction, the \$2 million in Gateway for Accelerated Innovation in Nuclear (GAIN) vouchers, for private companies to access national lab resources, is insufficient to support the technologies beyond the ARC programs.

Any effective goal must be understood by contributors at all levels, and used to actively guide and prioritize efforts. The current DOE portfolio is aimed at early research—as appropriate—but such research should be targeted at commercially relevant problems. The goal should be based on price points, time, and performance characteristics. It should be broad enough not to automatically exclude technologies, but specific enough to act as a forcing mechanism to identify cross-cutting research priorities, work through licensing issues, and guide cost-sharing with industry on new demonstrations.

For example, one possible goal would be for DOE to provide research facilities to enable the demonstration of at least four different advanced light water and non-LWR reactor technologies by 2026—a decade from now—producing power at \$65–70/MWh (or below) for the nth of the kind reactor in competitive markets.

While ambitious, I believe this is achievable. NuScale already has an arrangement with Idaho National Lab to deploy an SMR on site—targeting the early 2020’s. The ARC program has begun development of two specific technologies with the private sector, both of which would need to be accelerated to achieve this goal. It is now a question of broadening the technology portfolio, providing funding support, and accelerating the timing.

Third, government should work more closely with industry by complementing, not replacing, private sector innovation.

Advanced nuclear companies have already raised over \$1.5 billion in private capital, and the government and philanthropy need to leverage—not replace—that investment. End users of technologies—utilities and other potential customers—often make better decisions than government alone. DOE and the Office of Science and Technology Policy should collaborate closely with an advisory board of reactor designers, utilities, and other end-users and innovators to efficiently co-invest public and private capital to accelerate innovation efforts. Independent guidance from the private sector can identify research, commercialization, and deployment priorities with potential to help a broad range of technologies, keep that research on track, and result in technologies that are more innovative and commercially realistic than might be produced with DOE going it alone.

This private sector board’s mandate will include a strategy that supports development of more nascent but less mature technologies as well as demonstrating more mature technologies. DOE efforts should encourage a broad portfolio of technologies at different stages of maturity.

Focused in this way, DOE should see its role as investing in enabling tools and capabilities. Most of these tools exist today, but DOE should expand access to the private sector.

For example, advanced reactor companies need a supply and a technical understanding of a variety of fuel forms. The current process for qualifying new fuels takes 10 to 20 years, which alone could prove a nearly insurmountable barrier for most companies. Despite significant improvements in analytical capabilities, the fuel qualification process has not been simplified for many decades. Providing alternatives, such as use of analytical modeling of advanced nuclear fuels, is an area where DOE-funded research may prove essential to the rapid development of advanced reactors. Better communication on the quality of these tools will also enable NRC to leverage them to speed licensing.

In addition, we should learn from, and not repeat the mistakes of FutureGen or Solyndra—both recent examples of the government deciding to invest huge amounts of money into technologies with questionable commercial prospects. The DOE and NRC should continue recent efforts in the spirit of the GAIN initiative, and enable the private sector to develop their designs, remove regulatory roadblocks to enhance efficiency, create and maintain high-quality user facilities, and solve fundamental challenges. Recognizing that technology development benefits company profits as well as our energy system, industry cost-share must be part of the equation.

Fourth, our government must eliminate the silos that stifle progress on innovation.

Appropriators should work together with the Department to better enable cross-cutting nuclear initiatives outside of the standard funding framework. This is more effective than allotting specific budgets for various offices and specific national labs to work on specific individual line items.

We should stop funding tools, and start funding outcomes. DOE should be given the flexibility to work towards a goal, even when that goal spans multiple office and lab jurisdictions. This level of cooperation requires setting an ambitious national goal for advanced reactor development. Quantitative goals provide both accountability and flexibility. Research isn’t locked into programs that are deemed ineffective, and price and time targets help select efficient research pathways.

Two potential models for this approach that have generated results are the SunShot Initiative and the Joint Bioenergy Institute (JBEI). SunShot is a 10 year DOE initiative to reduce the cost of solar electricity to \$1/watt (.06¢/KWh) by 2020. Although only 5 years in, the initiative is already 70 percent of the way there. SunShot works closely with utilities, industry, and universities to conduct its work.

JBEI is a program working across multiple national labs with industry to drive cost reductions in biofuels and biopower. JBEI has a private sector board of advisors, continuously assesses which strategies are working and which are failing, and is about to hit its cost target of \$2.20/gallon of highly efficient, gasoline-equivalent

biofuel. While we can't predict whether their technology is the future of transportation fuel, their goal-based research model has produced results.

Each of these programs demonstrates that the DOE can work well with industry and achieve significant technology improvements when given a strong vision and checkpoints along the way. The same could be possible in nuclear energy.

America has an opportunity to continue to lead the global market for clean, safe, affordable, reliable, proliferation-resistant advanced nuclear reactors. Without a more focused government effort, we will not sustain our vital nuclear industry and control nuclear proliferation. We do not want these innovative American reactor designs to move offshore because of regulatory over conservatism and government inertia. ClearPath and our advisors are eager to assist in realizing this opportunity and currently have multiple cost benefit projects underway to support our positions in great detail. We look forward to making these reports publicly available.

Senator ALEXANDER. Thanks, Mr. Faison.
We'll have a round of questions.

ENERGY SUBSIDIES

Senator Gregg, you talked about spot pricing. Sometimes we talk about negative pricing. I'm going to ask you, since you're skilled as an economist in many ways, to explain to us the effect subsidies for wind, for example, have on nuclear power operation. One example of what's going on is, the subsidy for wind is so generous that, in some regulated markets, producers can actually give away the power and still make a profit. I know that we've got a company coming into Tennessee, and with plans to build these massive turbines that are twice as tall as our football stadium, destroy the landscape, and do it in an area where the Energy Information Administration says that the wind blows 18 percent of the time and where the Tennessee Valley Authority has said it doesn't need the power. So, the only justification, I would assume—only economic justification of them coming to Tennessee to do that would be that they're getting such a generous subsidy, they have to build those somewhere. But, talk about the effect of so-called spot pricing on nuclear power generation, and to what extent that contributes to the premature closing of reactors.

Mr. GREGG. Well, I am very familiar with the Senator's views on wind. Is it Bristol Motor Speedway now or is it the stadium?

Senator ALEXANDER. Well, it's going back to being a speedway. I think there's one more football—one more football game to be played.

[Laughter.]

Mr. GREGG. The issue for nuclear is that, because it does these good things, like reduce carbon and have reliability and be part of the diversity mix, it gets no credit for this in the marketplace the way that other types of energy production does get credit. And we're not against—our group has no position; in fact, most of us support alternative energy sources. But, what we're pointing out is that, with nuclear power, and especially the plants that are at risk of closing prematurely, they're being pushed into a situation which is primarily driven by the economics—and I know Senator Feinstein mentioned that Vermont Yankee was closed because of popular opposition. There was significant popular opposition in Vermont—Vermont Yankee, but it was actually closed, in the end, because of the numbers. And it's ironic, because all of Vermont Yankee's power is now being replaced by gas. And so, it's gone totally to a carbon production energy source to replace Vermont Yan-

kee, which was noncarbon. And that's an example of what happens when you don't reward nuclear for the fact it's not producing carbon and it's reliable and it's diverse. And so, what we've—suggesting is that, as States move through their plans for addressing a clean plan—Clean Power Plan or whatever they—however they decide to take on carbon emissions, such as New York has—that they consider the fact that if nuclear is to compete, because it is a long-term capital investment of significant amounts, it must get—it must be reflected in the process of reimbursement, the fact that they do not produce carbon, they are reliable, and that they are diverse.

CLEAN POWER PLAN

Senator ALEXANDER. But, the Clean Power Plan which is currently being appealed, I guess to the Supreme Court, if I'm correct about this, it would require States to come up with their plans by 2030—compliance is by 2030, so get their plan and—so their compliance with whatever the standards are, the reduction of carbon by 2030, that's—it takes a long time to build a nuclear reactor, at least under the current way of doing it, maybe 8, 10 years. And then, under the Clean Power Plan, as I understand it, you'd only get credit for the carbon-free emissions in the remaining years before 2030. So, there would be very little—so, it would seem to me that we're just introducing one more element of policy, the Clean Power Plan, in the name of carbon-free emissions that discriminates against the single largest producer of carbon-free emissions and makes it more difficult to build more reactors.

Mr. GREGG. Well, from our viewpoint, the Nuclear Matters viewpoint, we think that State-by-State decisions on this make sense, that some States are reacting to the Clean Power Plan proposal in a way that is constructive to nuclear power, such as Illinois and New York, but that it's going to depend on each State making its own decision. And, in making those decisions, if you've got nuclear plants in—operating in your region which are producing power and could continue to produce power, that are going to be prematurely closed because they're not being rewarded for the fact that they're noncarbon, that they're reliable, and they're diverse, then, in our opinion, these State plans should take that under consideration, whether it's pursuant to the Clean Power Plan or whether it's pursuant to a State decision, such as New York is doing.

Senator ALEXANDER. Thank you, Senator.

Senator Feinstein.

ENERGY MARKETS

Senator FEINSTEIN. Thanks very much, Mr. Chairman.

I sort of wanted to get into the difference that regulated versus unregulated markets make in the building of a plant. And my understanding is, all five reactors in the United States under construction today are in regulated electricity markets. And these markets can support the very large, long-term investments needed to make the power competitive. Also, utilities in these markets are allowed to pass on the costs of construction to consumers even before the plants are finished.

Now, utilities in deregulated markets aren't investing in nuclear power, because, I'm told, they don't have certainty about future electric—electricity prices, and sources like wind and natural gas are cheaper near-term options.

Mr. FAISON, what is your group's position on this regulated-versus-unregulated marketplace, in terms of the incentive to develop a reactor?

Mr. FAISON. I think that's a very good question. And regulated markets do have an advantage, in that they can look long-term, they can look 30, 40 years down the road and make sure that we have a diverse and reliable mix so that we don't have problems that the Senator spoke about. When the vortex came through, we had a spike in natural gas prices and the question about reliability. So, they're looking—they can look further down the road. I think they could sell that to public utility commissions. Whereas, a non-regulated utility has to buy the lowest-cost power, effectively, every day, and that preempts paying for that kind of dependability and reliability.

Now, wind being heavily subsidized gives that an advantage, where nuclear does not have that advantage. And that also, I think, distorts markets, particularly—

Senator FEINSTEIN. So—

Mr. FAISON. Sorry.

Senator FEINSTEIN [continuing]. Speak a little bit about how big this is in the consideration of whether you're going to go into a certain place. Is this an important determinant of whether you will go or not, whether the market is unregulated or regulated? For example, we have a regulated market.

Mr. FAISON. Right. Well, I—the only potential new plants that I know of—Southern just got approval for a plant—I think about 100 miles away from Vogtle, where they're going to start doing—apply for a license for a new generation-3 nuclear plant. I don't think we're going to see a lot more generation-3 light water nuclear plants, and certainly not in competitive markets.

I applaud Southern, because they are looking at the market as a whole, and they want to preserve the nuclear industry. They are employing advanced—well, people coming out of the Navy right now can't find jobs. The nuclear engineers—there's a big national security concern, I think, when our Navy nukes don't have jobs, coming out of the Navy, when we have power plants coming offline. For example, advanced welders, nuclear welders, a lot of those folks are down at Vogtle. And so, Southern has spent a lot of time and money training these people up, adding additional cost to build out these reactors, and they want to keep that supply chain and those benefits going. If they weren't building this next set of plants 100 miles away, I think it's really hard to rebuild supply chains as big and complex as nuclear, so I really applaud them for what they're doing.

Senator FEINSTEIN. So—

Mr. FAISON. It has to be in regulated markets.

Senator FEINSTEIN. Yes. It has to be a regulated market.

Mr. FAISON. In today's environment.

Senator FEINSTEIN. Yes.

Mr. FAISON. Unless we sort of change the rules, I think you're right. I think it has to be in regulated markets.

Senator FEINSTEIN. Senator Gregg, do you differ with that?

Mr. GREGG. Under the present rules, yes. However, if the State—

Senator FEINSTEIN. You differ, or you agree?

Mr. GREGG. No, I agree.

Senator FEINSTEIN. Oh, I see. Okay.

Mr. GREGG. But, under—but, you know, we're in a time of change. And as States and regions try to address the noncarbon reduction capabilities of their power sources, I think they're going to take a look at nuclear as an option which they can lock in over a long period of time, or they should. And certainly, in maintaining plants that have a useful life, that makes a lot of sense. So—

Senator FEINSTEIN. Well, that would be a good thing, then, for people that are interested in doing this to take a good look at the difference between regulated and unregulated markets. And that will certainly skew the base for nuclear power, it seems to me. Because if what you said is true, that you cannot build in a deregulated market today, effectively or efficiently, or be assured that you have some certainty, you're not going to do it. Is that not right?

Mr. FAISON. If you want to keep your job as the CEO, I think it would be difficult, right?

Senator FEINSTEIN. Yes, right. Okay, thank you very much.

Thanks, Mr. Chairman.

Senator ALEXANDER. Thanks, Senator Feinstein.

Senator Collins.

CLEAN-AIR BENEFITS OF NUCLEAR POWER

Senator COLLINS. Thank you very much, Mr. Chairman.

I'm so happy that my Aging Committee hearing, which I was chairing, ended in time so that I could get to the end of your important hearing, and particularly to welcome back our esteemed colleague and friend, Senator Gregg.

Senator Gregg, I was struck by the statistics in your written testimony about the magnitude of nuclear energy's clean air benefits. You said, and I quote, "Without the 99 nuclear power plants that operate in 30 States, carbon emissions from the U.S. electric sector would be approximately 25 percent higher."

As someone who's very concerned about climate change and the impact on coastal States like mine, where we're already seeing changes in our waters, I am puzzled why there is not more acknowledgment of the carbon benefits of nuclear power. And, as we were sitting here, I was thinking about all of the meetings that I have—and they are frequent—with environmental groups from Maine and nationally that I've had in the last couple of years because of our shared concern about climate change. And I cannot remember a single one of those meetings touching on the benefits of nuclear power to improving clean air and lessening carbon emissions, despite the fact that Maine is at the end of the Nation's tailpipe and receives emissions from coal-fired power plants, even though we don't have coal-fired power plants.

So, I guess that's largely a comment rather than a question, but I'm going to turn it into a question. And that is, why aren't the

clean-air benefits of nuclear power more widely promoted by those who are sincerely and fervently committed to efforts to reduce carbon emissions?

Mr. GREGG. That goes to me, Senator?

Senator COLLINS. Yes, it is.

Mr. GREGG. Thank you.

Senator COLLINS. I thought I'd try to stump you.

[Laughter.]

Mr. GREGG. Well, I can't really speak for the environmental community that you've been meeting with, because I don't know them. But, I can say that, amongst our group—and our group's purpose was to raise the level of education as to the importance of nuclear power, and specifically in the area of reducing carbon. And you cited the fact it's 25 percent. Try to put it in real terms that people can understand: If all the nuclear power plants were closed in this country, it's the equivalent of adding 115 million cars to the road. Staggering amount of emissions which will affect our environment and obviously affect the issue of global warming.

So, that's why we came together. It's a totally bipartisan group. And one of our members is Carol Browner, who was formerly head of the EPA and who was very active in the Obama administration, also, on environmental—and she openly admits that, at one time, as an active environmentalist, she was totally opposed to nuclear power. And she's moved 180 degrees, because she sees nuclear power as one of the key elements of addressing the global warming issue. And there are a number of people like Carol. And she's speaking, I think—it's starting to resonate.

But, it takes education. That's what it takes. And that's why we came together. We're an educational group, primarily, and we're trying to do exactly that, tell people that—proselytize the fact that nuclear power makes a lot of sense if you're concerned about this environment.

Senator COLLINS. Thank you. That's really interesting, about the former EPA Commissioner coming to be part of your group, as well.

ADVANCED REACTORS THAT REDUCE NUCLEAR WASTE

Mr. Faison, I think part of the issue is one which the Ranking Member mentioned just as I was getting here, and that is concern about nuclear waste. This is an issue in my State, where we have a decommissioned nuclear plant, and there's no repository to accept spent nuclear fuel. So, Maine has had to store that nuclear fuel on the site for decades now. And I'm interested—in your written testimony, you mentioned, briefly, advanced nuclear design concepts that are being developed. And I would ask you, How would they deal with the nuclear waste issue?

Mr. FAISON. Thank you for that question. I think Secretary Moniz could much more articulately—he could articulate that in a thoughtful way.

Having talked to nuclear entrepreneurs, and read a bit about it, a lot of those designs can use spent fuel, and they can process the fuel longer. It was very—there's a drastic reduction in the amount of waste that they produce. And nuclear waste—I think there is a bit of a misnomer on the amount of nuclear waste. I think right now we're sort of at four football fields stacked on top of one an-

other, as far as the total amount. So, I wish I could give you a better answer than that, except that a lot of these designs do—do what the France system does, which is regenerate the waste.

Senator COLLINS. Thank you, Mr. Chairman.

THE FUTURE OF NUCLEAR POWER

Senator ALEXANDER. Thank you, Senator Collins.

Building on Senator Gregg's testimony, you said, in your comments, that future that you see is an environment in which 30 to 40 percent of our electricity is produced by nuclear. Is that correct?

Mr. FAISON. That's a goal. It's a—

Senator ALEXANDER. Yes. That's a goal. And today it's 20 percent.

Mr. FAISON. Correct.

Senator ALEXANDER. And we know that maybe half our reactors may close in the next 20 years.

Mr. FAISON. Right.

Senator ALEXANDER. So, a few years ago, I recommended—5 years ago, in a speech at Oak Ridge—that we build 100 new reactors. People thought that was a fanciful idea. It seems to me, if you add it up, that we'd have to build at least 100 new reactors, or the equivalent of that, if we were to have any chance of getting to 30 to 40 percent of our electricity produced by nuclear by the year 2040. What's your comment on that?

Mr. FAISON. It sounds like we're aligned.

Senator ALEXANDER. Yes.

Mr. FAISON. But, I do have quite a bit of passion around this, having spent a lot of time at the Department of—not a lot of time—a week, a great week, touring the Labs, including Oak Ridge, and was incredibly impressed about the, sort of, national treasure we have there. But, a lot of folks that work there, when I asked, sort of, "What do you need?"—I heard, over and over again, "Goals." And, you know, I'm a little bit of a sap on this. I think America could still do great things, but I think we have to aim at great things. You're definitely not going to hit something you don't shoot at. And I don't know what we're shooting at. And the people that I find in this industry don't know, either.

And I think we have to set big—these are big, huge, long-term projects, with multiple inputs. I think we need to identify the bottlenecks, we need to be ready to really roll up our sleeves across a lot of different sectors. And, without goals, and working towards longer-term goals, then backing down to shorter-term goals, as a business guy, I don't know how you do that. Smarter people than me might know, but I—that's what I struggle with.

So, we want to be, maybe, an instigator, if you will, on—try to stack up these goals and then work backwards to the things that we think we need to get there. And I think a short-term goal of four to five advanced, demonstratable concepts on a site like Idaho National Labs, where you have NuScale demonstrating their—they've been, I guess, approved to start building that test site—without a diversity of technologies and a hard push to it in the short term, I think our nuclear energy percentage, as a whole, is going to go down, and we're going to have a decimated industry

that will not give us the capability to do much in the future around nuclear.

Our average employee in the nuclear industry, I believe, is 56 years old; and roughly 25 percent of these employees, these workers, are going to retire in the next 5 years. So, I think we're actually at a very critical juncture, here. And when I went to the Nuclear Energy Conference, the NEI Conference, there are a lot of young people that want ambitious goals, and they're coming into this industry with a chance to attack carbon emissions. And I think we've got to give them something to shoot for.

So, sorry for the long-winded answer, but I couldn't agree with you more. We need to set big, ambitious goals.

NUCLEAR PLANT CLOSURES

Senator ALEXANDER. Thanks.

Senator Gregg, I'll ask you one last question. Three reactors in New Jersey, Massachusetts, and New York, up in your neck of the United States, are scheduled to close in the next few years. We've talked about—Vermont Yankee, which closed a couple of years ago, had the capacity for providing Vermont 70 percent of its electricity, but now it doesn't. And they've chosen, instead, to take a carbon-emitting source of electricity.

On the other hand, New York, instead of closing a plant, is trying to find a way to keep one open. You say Illinois may be doing the same. Do you see a shift in attitude?

Mr. GREGG. Yes, I do. And it's driven by people being concerned about carbon emissions and global warming, and common sense taking hold. It's a commonsense answer that you don't shut down your noncarbon-emitting energy source to replace it by carbon-emitting energy sources. In fact, hopefully, even in Massachusetts, the closure there may be reconsidered. I'm not sure of it, but that's a possibility, because you're going to end up with—

New England's a unique situation. You know, we don't have a natural energy source. We don't have coal, we don't have gas. What we have is nuclear power. New Hampshire still has a nuclear plant. So, when we shut a nuclear plant down in New England, we have to not only replace it with carbon-emissions, and we also lose reliability if we hit another polar vortex—and it does get fairly cold in New England on occasion, mostly in Maine—she's not here to defend herself anymore—but, we have to import the energy.

So, one of our—when I was Governor of New Hampshire, one of our advocacy points was, "We have our energy source right here." Now we don't, in western New Hampshire.

So, it really is a "cut off your nose to spite your face" approach to close nuclear plants prematurely, and that's the case we've been making. And I think it's getting traction, because I think people see—you know, American people are inherently filled with common sense. That's one of our great strengths as a Nation. When you explain the issue to folks, they pretty much get it.

Senator ALEXANDER. Thank you.

THE FUTURE OF NUCLEAR POWER

Senator Gregg, thank you. Mr. Faison, thank you. This has been our first hearing on the future of nuclear power. Our purpose in

this is, just what you stated, to try to focus attention on the irony and the inconsistency of, on the one hand, having a national goal to produce carbon—to reduce carbon, but, at the same time, closing nuclear plants and making it harder to build new ones at a time when nuclear produces 60 percent of your carbon-free electricity. It makes no sense whatsoever, and it's apparently—certainly makes no sense for the same people to be urgently arguing to deal with climate change and then either quiet or urgently opposed to nuclear power.

I'd like to also say, because I think it's important to say at any nuclear hearing, there's never been a death at a nuclear power plant as a result of a reactor accident in the United States; nor, since the 1950s, there's never been a death in connection with a reactor accident in the nuclear Navy. Our most celebrated nuclear accident in the United States was Three Mile Island, in Pennsylvania, in 1979, I guess, and no one was hurt at Three Mile Island. So, if we're looking for a form of electricity production that we know a lot about, that produces reliable, clean, and safe electricity, and helps meet our low-carbon future, nuclear certainly ought to be a part of our future.

Without objection, the written testimony from our witnesses will be included in the record. Hearing record will remain open for 10 days. Senators may submit additional information within that time. The Subcommittee requests all responses to questions be provided within 30 days of receipt.

SUBCOMMITTEE RECESS

Senator ALEXANDER. The Subcommittee thanks the witnesses and stands adjourned.

[Whereupon, at 4:48 p.m., Wednesday, September 14, the subcommittee was recessed, to reconvene subject to the call of the Chair.]

THE FUTURE OF NUCLEAR POWER, PART II

WEDNESDAY, NOVEMBER 16, 2016

U.S. SENATE,
SUBCOMMITTEE ON ENERGY AND WATER DEVELOPMENT,
COMMITTEE ON APPROPRIATIONS,
Washington, DC.

The subcommittee met at 2:33 p.m. in room SD-138, Dirksen Senate Office Building, Hon. Lamar Alexander, (chairman) presiding.

Present: Senators Alexander, Feinstein, Tester, Udall, and Shaheen.

OPENING STATEMENT OF SENATOR LAMAR ALEXANDER

Senator ALEXANDER. The Subcommittee on Energy and Water will please come to order. This afternoon we'll have the second of two oversight hearings to discuss the future of nuclear power in the United States.

In our previous hearing in September, we discussed what actions should be taken to maintain today's nuclear power plants and to ensure our country continues to invest in nuclear power.

Today we'll discuss the recent Task Force Report on the Future of Nuclear Power from the Secretary of Energy's Advisory Board. We'll also discuss basic energy research and development to support nuclear power, the work that's being done to safely extend reactor licenses from 60 to 80 years where appropriate, and the development of new nuclear technologies, including advanced reactors, small modular reactors, and accident-tolerant fuels.

Senator Feinstein and I each will have an opening statement. I will then recognize each Senator for up to 5 minutes for an opening statement, and we'll go from there.

We'll then turn to the witnesses for their testimony. The first panel will be Dr. John Deutch. He is Chair of the Secretary of Energy's Advisory Board and an Institute Professor at MIT. He is a former Director of CIA, Deputy Director of Defense, and Director of Energy Research at the Department of Energy.

The second panel includes Dr. Alan Icenhour and Dr. Matthew McKinzie. Dr. Icenhour, Associate Lab Director for Nuclear Science at Oak Ridge National Laboratory. Dr. McKinzie, Director of the Nuclear Program at the Natural Resources Defense Council.

After that, we'll have some questions.

Now I would like to make a brief opening statement. Today's hearing, as I said, is our second oversight hearing to discuss steps we can take to ensure that carbon-free nuclear power has a strong future in our country.

Our first hearing, we heard from Secretary Moniz about the challenges. We heard about research, a lot of which is being done at our national laboratories, including Oak Ridge.

We heard Senator Whitehouse, who is very concerned about climate change, tell us that in his view it made no sense to close carbon-free reactors at the same time we're trying to deal with climate change.

We also heard from Senator Judd Gregg and Jay Faison, CEO of the ClearPath Foundation, who gave us much of the same message and talked about the amount of innovation, 40 to 50 companies are working on advanced reactor concepts that would lower construction costs, increase safety, and make better use of fuel management than today's reactors.

FUTURE OF NUCLEAR POWER

I believe the future of nuclear power can be bright, but that we need to prepare now by building more reactors; by ending the stalemate on what to do about nuclear waste, Senator Feinstein and I are united on that; stopping Washington from picking winners and losers in the marketplace, which sometimes disincentivizes the use of nuclear power; pushing back on excessive regulation; and fueling more free market innovation with government-sponsored research.

TASK FORCE REPORT

The witnesses today will discuss the Task Force Report I mentioned, R&D, and steps we can take to maintain the fleet.

We received the report in October of the Secretary's Energy Advisory Board, which examined the challenges that the nuclear industry is facing, as well as steps necessary to develop new technologies. It emphasized, and I'm sure Dr. Deutch will talk about, five factors limiting investment in nuclear power in our country. First is that nuclear power doesn't get enough credit for being carbon-free. Second, new nuclear technologies are complex, expensive, and heavily regulated. Third, we haven't solved the nuclear waste stalemate, which has been going on now more than 25 years, the stalemate, market conditions and unanticipated events, such as an accident.

At a time when leading science academies of 20 developed countries and many Americans say climate change is a threat and that humans are a significant cause of that threat, nuclear power produces 60 percent of our country's carbon-free electricity, and power plants produce nearly 40 percent of the carbon produced in our country.

Now, just speaking for myself, in my hometown of Maryville, Tennessee, if I had 20 fire marshals of repute come around and tell me my house might burn down, I might buy some fire insurance. So my recommendation is that we should get some insurance in this country against climate change, and I think the best insurance in the near term is nuclear power. It makes no sense to close reactors at a time when people believe climate change is a problem.

NEXT GENERATION ON NUCLEAR REACTORS

We need to invest in the next generation of reactors. We need to continue to work with the Regulatory Commission to move forward with small modular reactors. Our bill, the appropriations bill of this committee, includes \$95 million for that work.

The Task Force recommends we undertake an advanced nuclear reactor program to support the design, development, demonstration, licensing, and construction of a first-of-a-kind commercial scale reactor. I'm looking forward to hearing more about that from Dr. Deutch.

Dr. Icenhour, who is here today on behalf of the Oak Ridge Laboratory, leads a consortium for advanced simulation of light water reactors. We're looking forward to hearing his discussion of that.

INTERIM STORAGE FACILITY

Secretary Moniz said at our hearing that by the end of the year, the Department would begin the process of moving forward with interim storage facilities for nuclear waste. That's something Senator Feinstein and I congratulated him for and have encouraged.

And I'm pleased to report after our hearing, the Department took the initial step of seeking information on private interim nuclear waste storage sites. We need to move on all tracks at the same time to solve the nuclear waste stalemate, and I appreciate the Secretary's attention to this.

Secretary Moniz took that important step. The new Congress should take the next steps and pass the Bipartisan Nuclear Waste Administration Act, introduced last year by Senators Feinstein, Murkowski, Cantwell, and me. Congress should pass the pilot program that would allow the Secretary to take title to used nuclear fuel. Both the pilot program and funding for private interim storage were included in this year's Senate Energy and Water Appropriations bill that Senator Feinstein and I have recommended and the committee approved.

EXISTING NUCLEAR FLEET

We need to maintain our existing nuclear fleet. We need to extend reactor licenses from 60 to 80 years where it's appropriate and safe to do so. We need to relieve the burdens of unnecessary regulation, to use our supercomputing resources. Since our hearing, another reactor has shut down, Fort Calhoun Nuclear Generation Station shut down on October 24th, which means we've lost another 484 megawatts of carbon-free electricity.

In conclusion, I would say this, imagine a day when the United States is without nuclear power. That's a day I don't want to see in our country's future. It seems distant and unlikely, but it's a real threat. By 2038, just 20 years from now, 50 reactors will have reached 60 years of operation, representing 42 percent of the nuclear generating capacity in the United States. So our country could lose about half our reactors if existing licenses can't be extended from 60 to 80 years, and those reactors close.

While there are four new reactors being built, all in the Southeast, there are eight reactors, three in the Northeast, at seven sites, which are scheduled to shut down by 2025. The Energy Infor-

mation Administration estimates that shutting down these eight reactors, plus the recent closing of Fort Calhoun, will result in a 3 percent increase in total carbon emissions from the U.S. electricity sector.

We need to take steps today to ensure nuclear power has a future in our country. And with that, I would like to recognize Senator Feinstein, our committee's distinguished Ranking Member, for her opening statement.

[The statement follows:]

PREPARED STATEMENT OF SENATOR LAMAR ALEXANDER

The Subcommittee on Energy and Water will please come to order.

This afternoon we will have the second of two oversight hearings to discuss the future of nuclear power in the United States.

In our previous hearing, in September, we discussed what actions should be taken to maintain today's nuclear power plants and ensure our country continues to invest in nuclear power.

Today, we will discuss the recent Task Force Report on the Future of Nuclear Power from the Secretary of Energy's Advisory Board.

We will also discuss:

- Basic energy research and development to support nuclear power;
- The work that's being done to safely extend reactor licenses from 60 to 80 years; and
- The development of new nuclear technologies, including advanced reactors, small modular reactors, and accident tolerant fuels.

Ranking Member Feinstein and I will each have an opening statement.

I will then recognize each Senator for up to five minutes for an opening statement, alternating between the majority and minority, in the order in which they arrived.

We will then turn to the witnesses for their testimony. The first panel will be Dr. John Deutch.

He is the Chair of the Secretary of Energy's Advisory Board and an Institute Professor at the Massachusetts Institute of Technology.

He is also a former Director of the Central Intelligence Agency, Deputy Secretary of Defense, and Director of Energy Research at the Department of Energy.

The second panel includes Dr. Alan Icenhour and Dr. Matthew McKinzie.

Dr. Icenhour is the Associate Laboratory Director for Nuclear Science and Engineering at the Oak Ridge National Laboratory.

Dr. McKinzie is the Director of the Nuclear Program at the Natural Resources Defense Council.

After witness testimony, Senators will then be recognized for five minutes of questions each, alternating between the majority and minority in the order in which they arrived.

* * *

Today's hearing is our second oversight hearing to discuss steps we can take to help ensure that carbon-free nuclear power has a strong future in this country.

In September we held our first oversight hearing on the future of nuclear power, and we heard from Secretary Moniz about the biggest challenges facing nuclear power, and the work the Department of Energy is supporting in nuclear research and development programs to help solve those problems. A lot of that research and development is performed at Oak Ridge National Laboratory, and the other laboratories. We'll hear more about that today.

At that hearing, Senator Whitehouse discussed his efforts to drive innovation in next generation nuclear technologies at our national laboratories, and foster a regulatory environment that enables these technologies to come to market. He explained the reasons he supports advanced nuclear reactors—compared to today's reactors, they are potentially safer, less costly, may produce less used fuel.

We also heard from former Senator Judd Gregg and Jay Faison, CEO of ClearPath Foundation. Senator Gregg said it makes no sense to close down nuclear reactors if they still have useful life. He explained how nuclear plants are closing, in part because they are competing with other forms of energy that are highly subsidized. Mr. Faison talked about the innovation—he said 40 to 50 companies are working on advanced reactor concepts that have lower construction costs, increased safety and better used fuel management than today's reactors.

Our nuclear future can be bright, but I believe we need to prepare now by:

- building more reactors;
- ending the stalemate on what to do about nuclear waste;
- stopping Washington from picking winners and losers in the marketplace;
- pushing back on excessive regulation; and
- fueling more free market innovation with government sponsored research.

The witnesses today will discuss:

- The Secretary of Energy Advisory Board Task Force Report on The Future of Nuclear Power;
- Research and development of the next generation of nuclear reactors;
- Steps we can take to maintain our existing reactor fleet:
 - Recognizing nuclear as a carbon-free source of electricity;
 - Extending reactor licenses from 60 to 80 years if it is safe to do so; and
 - Solving the nuclear waste stalemate.

In October we received the Secretary of Energy Advisory Board Task Force Report on The Future of Nuclear Power.

The report examined challenges that the nuclear industry is facing today, as well as the steps that are necessary to deploy new advanced nuclear technologies in the future.

The report concluded that there are five factors that are limiting investment in nuclear power in the U.S.:

- Nuclear power does not get credit for being carbon-free;
- New nuclear technologies are complex, expensive and are heavily regulated;
- We have not solved the nuclear waste stalemate;
- Market conditions; and
- Unanticipated events, such as a nuclear accident.

At a time when the leading science academies of 20 developed countries, and many Americans, say climate change is a threat—and that humans are a significant cause of that threat—nuclear power produces about 60 percent of our country's carbon-free electricity.

Power plants produce nearly 40 percent of the carbon produced in our country.

If in my hometown of Maryville, I had twenty fire marshals come around and tell me my house might burn down, I think I would buy some fire insurance.

So my recommendation is that we should get some insurance against climate change.

I think the best insurance is nuclear power. It makes no sense whatsoever to close reactors at a time when many people think climate change is a problem.

We need to invest today in the next generation of nuclear reactors, advanced reactors, small modular reactors, and accident tolerant fuels.

The Department of Energy should continue to work with the Nuclear Regulatory Commission to move forward with small modular reactors, a technology I strongly support.

The Senate Energy and Water Appropriations bill includes \$95 million for this work.

The Task Force recommends that the United States undertake an advanced nuclear reactor program to support the design, development, demonstration, licensing and construction of a first-of-a-kind commercial-scale reactor.

Dr. Icenhour, who is here today on behalf of Oak Ridge National Laboratory, leads the Consortium for Advanced Simulation of Light Water Reactors, also known as CASL.

Dr. Icenhour and his colleagues at our national laboratories are currently developing the advanced nuclear technologies that will be needed to ensure nuclear power has a future in our country.

Secretary Moniz said at our hearing that by the end of the year the Department would begin the process to move forward with interim storage facilities for nuclear waste.

Solving the nuclear waste stalemate is a priority that Senator Feinstein and I agree on.

I am pleased to report that after our hearing the Department took the initial step of seeking information on private interim nuclear waste storage sites.

We need to move on all tracks at the same time to solve the nuclear waste stalemate, and I appreciate the Secretary's attention to this issue.

Secretary Moniz has taken an important step. Now Congress should take the next steps, and pass the bipartisan Nuclear Waste Administration Act, which was introduced last year by me, and Senators Feinstein, Murkowski, and Cantwell. Congress should also pass the pilot program that would allow the Secretary to take title to used nuclear fuel. Both the pilot program and funding for private interim storage were included in this year's Senate Energy and Water Appropriations bill.

We need to maintain our existing nuclear fleet and extend reactor licenses from 60 to 80 years if it is safe to do so.

We need to relieve the burdens of unnecessary regulation. We want to be safe, but we don't want to make it so expensive and difficult to build reactors that we don't build them.

We need to use our supercomputing resources to model and simulate reactor designs in ways that we never could before to make sure new reactors are safe and more cost-effective.

Since our hearing another reactor has shut down—the Fort Calhoun Nuclear Generating Station in Nebraska shut down on October 24 which means we have lost another 484MW of carbon-free electricity.

Imagine a day the United States is without nuclear power—a day I don't want to see in our country's future.

That seems like a distant and unlikely scenario but in fact it's more of a threat than many people realize.

By 2038—that's just over 20 years from now—50 reactors will have reached 60 years of operation, representing 42 percent of the nuclear generating capacity in the United States. The U.S. could lose about half our reactors if existing licenses can't be extended from 60 to 80 years and those reactors close.

While there are four reactors being built, all in the southeast, there are eight reactors, three in the northeast, at seven plants, which are scheduled to shut down by 2025.

The Energy Information Administration estimates that shutting down these eight reactors, plus the recently closed Fort Calhoun reactor, will result in a 3 percent increase in total carbon emissions from the U.S. electricity sector.

We need to take steps today to ensure nuclear power has a future in our country, and with that, I'd like to recognize Senator Feinstein, our subcommittee's ranking member, for her opening statement.

STATEMENT OF SENATOR DIANNE FEINSTEIN

Senator FEINSTEIN. Well, thank you very much, Mr. Chairman. And I think you know that there really is no one that I respect more in the Senate from either party than you, and one of my great pleasures has been to work with you. And on most things we have agreed.

We do not agree on nuclear power, as you know. And so because I'm a history major, I thought that I might, in my opening remarks, just cite some facts of history about the nuclear experience.

ADVANCE REACTORS

I think examining the potential risks and opportunities of advanced reactors is important. They're in competition with Federal research funding, with other clean energy sources, and the 4,400 megawatts of California's nuclear power, which is in the process of being shut down, will be replaced with clean energy, and California is going to aim to make 50 percent of its power all clean power before too long.

Now, some may claim the future is bright for this technology. I suggest otherwise. Advanced nuclear reactors are those that achieve higher efficiencies in electricity production through the use of graphite, salts, and metals as coolants and moderators instead of water.

In 1956, United States Navy Admiral Hyman Rickover, the father of our nuclear Navy, said of advanced reactors, and I quote, "They are expensive to build, complex to operate, susceptible to prolonged shutdown as a result of even minor malfunctions, and difficult and time-consuming to repair." And strangely enough, his words have been prophetic.

In 1965, the Fermi sodium-cooled fast reactor went online in Southeast Michigan. Ten months later, it suffered a partial melt-down when a coolant inlet became blocked and the core overheated. It operated briefly again from 1970 to late 1972, when it was shut down due to cost issues. The plant took 9 years to build, and operated for only 3 years.

Then in the 1970s, the United States spent over a billion dollars on the Clinch River Breeder Reactor project in eastern Tennessee. Costs were initially estimated at \$400 million, but by 1983, the GAO (Government Accountability Office) said the project would cost \$8 billion, something that we go through with uranium and plutonium processing now. Congress abandoned the project before construction was completed.

President Carter, a nuclear engineer, said of the project, and I quote, "The Clinch River Breeder Reactor is a technological dinosaur. It's an assault on our attempts to control the spread of dangerous nuclear materials. It marches our nuclear policy in exactly the wrong direction."

Now, these are fundamentally the same reactor designs we're still discussing today.

More recently, the Monju fast-breeder reactor in Japan operated for only a few months in 1994 and 1995 before a coolant leak caused a fire. Then it operated again for 3 months in 2010 before another accident during a refueling. After spending \$12 billion building, briefly operating, and repairing the facility, the Japanese government decided last month to abandon the project once and for all.

The recent history in the United States is not much better. The Energy Policy Act of 2005 authorized DOE to work with industry to develop a next-generation nuclear plant. The plant was intended to process heat and hydrogen for use in industrial applications. The program included cost-shared research and development activities with industry that would eventually lead to a demonstration facility.

By 2012, this committee had invested \$550 million in the next-generation nuclear plant, and was ready to move into Phase 2 by inviting industry participation, but not a single company could be found to put up the meager \$40 million cost share that was needed. DOE ended the program in 2013 because the government could not justify spending millions to develop advanced reactor designs that have no real support from the industry.

Even if advanced reactors overcome their history of disappointment, this Congress has not yet grappled with the need to find a workable solution to nuclear waste despite the best efforts of this committee. A bottom line fact is that the existing fleet of reactors has generated 77,000 metric tons of highly radioactive spent fuel. That staggering amount is growing by an average of 22 tons per year.

Even if some advanced reactor designs someday run more efficiently or even consume more spent fuel, a future built on nuclear power is impossible if we don't have a solution for dealing with existing waste.

Mr. Chairman, the Nation faces real challenges in addressing climate change, grid reliability, increased energy efficiency, and a

proper mix of generation sources. In each of these areas, this committee funds complex and necessary programs for research. I don't see how we can afford to divert several billion more dollars from these programs in order to explore speculative technologies that the industry itself has shied away from.

I think nuclear power must overcome its own significant shortcomings—one, astronomical upfront costs; and, two, waste that is toxic for thousands of years—if nuclear is to be a significant solution to our climate challenges.

Before this committee decides to devote significant new resources to the development of advanced nuclear reactors, I believe we need to see three things: one, a solution to nuclear waste, long term and viable; two, an indication that these reactor designs can overcome their history of technical shortcomings; and, three, an industry willing to make a financial commitment on its own. And I know that's a tall order.

So I very much look forward to our witnesses today. I've known John Deutch for a long time. I have great respect for him. And I look forward to listening to his testimony and the others.

Senator ALEXANDER. Thank you, Senator Feinstein.

Senator Tester.

STATEMENT OF SENATOR JON TESTER

Senator TESTER. Yeah, I'll be brief. First of all, thank you, Mr. Chairman and Ranking Member Feinstein, for having this hearing. I think this is a good discussion to have and talk about the challenges. And I appreciate you, Mr. Chairman, bringing up climate change because it's occurring whether we want to deny it or not, it's happening. I've been on the farm now since 1978, and things are happening that never ever happened before. Some of them are good, but a lot of them aren't so good.

And just for full disclosure, and I've been farming my whole life, I lost more money on an investment in an electrical energy company that had a nuclear power plant than I ever lost in anything else I've ever done in life.

So with that aside, I certainly don't have issues with the power. I think that there are positive things about the environment from a CO₂ standpoint. And I think Dianne, Senator Feinstein, brought up some points on reactor design.

NUCLEAR WASTE

The waste is the problem. We've got to figure out how you can repurpose it and get it done if we're going to do this. We may be changing CO₂ for nuclear waste, and I don't think we want to do that. I think we want to make sure that if we're going to have something that our kids and grandkids and generations and generations from now can deal with, it's got to work. And so I appreciate the hearing. I think it's a good discussion. And I don't think anybody on this committee, and I certainly have the utmost respect for you, Mr. Chairman, wants to do something that our kids are going to have to pay for forever. So thank you very, very much.

Senator ALEXANDER. Thank you, Senator Tester.

Senator Udall.

Senator UDALL. Mr. Chairman, I'm ready to proceed to the witness. Thank you.

Senator ALEXANDER. Thank you, Senator Udall.

Dr. Deutch, usually we ask witnesses to take about 5 minutes because that gives more time for questions, but you're the only witness on the first panel, and you've worked long and hard on a Task Force Report, plus you've got a lot of experience, so if you need more time than that, why don't you take it.

STATEMENT OF HON. JOHN DEUTCH, INSTITUTE PROFESSOR, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CHAIR, SECRETARY OF ENERGY ADVISORY BOARD

Dr. DEUTCH. Thank you very much, Mr. Chairman.

Thank you, Senator Feinstein, Senator Udall.

I'm very pleased to be here. I was chair of the Secretary of Energy Task Force—

Senator FEINSTEIN. Could you speak directly into the mic, John?

Dr. DEUTCH. Yes. Is that better?

Senator FEINSTEIN. Better.

Dr. DEUTCH. If it's not, poke me again and I'll do better.

TASK FORCE

So I'm here to report to you on this Task Force that I chaired, and I want to make clear what our task was. The Secretary asked the Task Force to describe an initiative that had the potential of giving the country the option, the ability, to have between 5- and 10,000 gigawatts of electricity built annually in the time period 2030 to 2050. That was our task.

Many other questions about nuclear power were not part of our task. So what would the country have to do to restore the level that, for example, was here when I joined the Department of Energy in 1976? That was the task.

The summary report, I mean the report and summary charts, are in the public domain. They've been supplied to committee staff, so I'm just going to focus on the main views of the committee, what were the message we want to—of our Task Force, what the message is, and then say a few words about five or six main findings.

NUCLEAR INITIATIVE

So here are the main takeaways. If the country is going to have a nuclear option in 2030, it must undertake an initiative of the scope and size that this committee described. It doesn't have to be exactly the same, but if you do not undertake a major initiative now, it is inevitable that in 2030 the country will not have a nuclear option.

Secondly, any such initiative is going to require time, considerable Federal resources, redesign of electricity markets, and sustained and skilled management.

Third, there is no shortcut to doing this. There is not going to be a magic technology provided that at low cost quickly can get you safe and reliable nuclear power.

Those are the takeaway messages.

CENTRAL TASK REPORT FINDINGS

So I want to now speak to the five or six central findings, recommendations, of the Task Force Report.

First, as you know, the nuclear fleet is aging, and there have been a number of early retirements. The early retirements are due in many respects to the rules governing electricity rates and dispatch that differ in different parts of the country, which makes it challenging to have value-based nuclear power. Examples include the structure of rates in wholesale capacity markets, preferential dispatch rules for renewable generation, exclusion of nuclear power from renewable portfolio standards, and rates that are inadequate to assure recovery investment.

The Task Force Report makes several suggestions for redesign of market rate structure, but for existing plants, this has to be done on a State-by-State basis, and different States are approaching it in different ways. New York came to some agreement which seems to be suitable for that State. I believe that Illinois is under detailed discussions at the present time, but fundamentally for existing reactors, that disparity in market structure has to be addressed at a State level, and it's not going to be changed easily.

The outlook for the construction of nuclear plants in the United States and other OECD (Organization for Economic Cooperation and Development) countries is bleak primarily because of the high overnight capital cost of nuclear power, roughly \$5,000, compared to natural gas, \$1,000 or less, which makes the levelized cost of nuclear power for the foreseeable future higher than the closest competitor, which is at least for the time being with low natural gas prices being levelized cost of electricity from natural gas.

The cost disparity would be greatly diminished if the carbon-free nature of nuclear power were recognized. It could be recognized in two ways, by the assessment of a carbon emission charge based on the social cost of carbon on fossil fuel generating electricity plants or, alternatively, on a production payment to new nuclear plants, not existing nuclear plants, for their carbon-free—that you recognize their carbon-free character. That is on the order of 2.7 cents per kilowatt hour. That is their carbon-free equivalent value.

Let me note that wind and photovoltaics, solar electricity generation, have that same carbon-free character and indeed do have an ongoing through the investment tax credit, a contribution for the taxpayers of this country roughly comparable to the 2.7 cents I mentioned before. So that would be a rule that I would apply to all new carbon-free electricity generation.

The Task Force actually recommends a two-part program. It is not only about advanced nuclear reactors.

The first point is, are there light water reactor technologies which will lead to new plant constructions of lower cost and which have other advantages, such as a small modular reactor? So the first aspect of the recommendations is pursue promising light water reactor technologies, which no longer have an unproven technology, but which have the practical questions of cost, licensing, siting, waste management. That's our first, but all new plants need to have a 2.7 cent production payment or its equivalent in order

to prove itself competitive with natural gas generation, which is generating, of course, carbon.

For advanced reactors, based on new technology, the Task Force recommends a four-part program to bring an advanced program from the research level to the construction of a first-of-a-kind plant, first-of-a-kind commercial plant.

The Task Force based its estimate of the time and cost of that as being \$11.6 billion with huge uncertainty around that number, and taking about 25 years. An important aspect of that judgment was based on carefully looking at a stage-by-stage development program from concept all the way to construction of a first commercial scaled plant.

There are many people who believe that could be shortened, and indeed it was mentioned, Mr. Chairman, there are 20 or 30 venture capital-based firms which are exploring all different sorts of technologies. They would see optimistically a much smaller time and cost for going through this development process for an advanced reactor.

We don't believe that's so, and we believe one important way of deciding is to compare the template for development that the Task Force has proposed with a template for development that the private sector firms are suggesting.

In any event, the point I want to leave with the committee is in our judgment, roughly speaking, this is a \$6.5 billion program for the period from selecting a plant all the way to the point where you develop where you start spending money on your first commercial plant.

We talked about financing of that. We believe that it should be in a well-run program, half, roughly half, provided by the Federal Government, mostly in the early stages where there are great technology efforts to reduce technology risks, and the latter half, more by private sector investors who see the practicality of these new reactor types.

Let me next turn to fuel cycle and waste management. I should say to you that when I was in the Department of Energy in the mid-'70s, the Department confirmed President Ford's decision not to do commercial reprocessing of spent fuel, and the Department continually proposed no additional funding for Clinch River Breeder Reactor, but there was a great effort to maintain light water reactor technology and the base nuclear technology for next-generation plants.

But there is no question about it, that advanced reactors will have a different fuel cycle, and therefore require different approaches for both licensing and for waste management. That is part of the challenge of moving to a new generation of reactors.

Now, we recommend for the management of this program that we propose, this 25-year, \$11.9 billion, \$11.6 billion program, the creation of a quasi-public corporation created by the Congress with a one-time appropriation for that long period of a difficult technical task going through several different administrations to pay attention and responsibly execute this program. I notice that the Blue Ribbon Task Force that you mentioned, that you both support, as I understand it, of Lee Hamilton and Brent Scowcroft, recommends exactly the same sort of a creation of a quasi-public corporation to

carry out the waste management part of this challenge. There may be a possibility for having a single, as committee staff has suggested to me, quasi-public corporation to carry out both the waste management piece and the new reactor development piece.

The NRC (Nuclear Regulatory Commission) today only has recent experience with licensing light water reactor plants. That means if you want to proceed to an advanced reactor, the NRC must develop the capability to do that licensing carefully. It's going to require more time and more resources for the NRC to do that job. We believe, and in our report we discuss—we have two ex-chairs of the Nuclear Regulatory Commission on our Task Force, a staged approach for the licensing of the advanced reactors that we believe deserves attention.

Some developers may choose to construct and license new advanced reactors in other countries, for example, China. I remind those developers, and everyone here, that the first time one of those plants come back into the United States, it will have to go through the whole entire NRC process again, so we will always have the oversight of the NRC prospect.

My final point, Mr. Chairman, has to do with international linkages. For a long, long time, the counterproliferation policy of the United States, where we've been a world leader, has been based on the influence we have through our knowledge and our activities in nuclear power technology.

As you know, the plants which are going to be built around the world are not going to be in Europe, they're not going to be in the United States, they're mainly going to be in China, in India, in Russia, in several countries in Asia, which this will be their first plant, the Emirates, Turkey, Jordan. We want to make sure that the proliferation and safety of those—the proliferation resistance of those plants is maintained. We have a national security interest in maintaining our international activities, especially in safety in the future of nuclear power.

I want to make a concluding remark. The Task Force, completely unanimous with this report, we had a wide range of people with different experience and backgrounds, unanimous, especially unanimous on the point that if the United States does not undertake an initiative like this, the nuclear option is not going to be there in 2030.

Now, that leaves open the broader question Senator Feinstein addressed. Does the country need this? Is it a practical thing that we can do given the fact that we have a changing administration all the time?

And there are very widely ranging different views on that. So it's not the case that everybody on our Task Force believes the country must do exactly this, but we all agree that if you don't do something like this, there is no possibility of nuclear power.

Then there is a set of people who say, well, what is the consequence of not having that base load generation, can it all be done with clean power or renewable sources? Differences of view on that, too. It depends very heavily, as you—as this committee knows, on how the grid develops.

But let me say it again, we give you a program to consider, which is in the scale of both time and dollars, one way of getting

possibly a substantially 30 percent or so cheaper, not zero cost, nuclear power in the future. And we raise a warning that if you don't do something like this, the country does not have a nuclear option in the future.

Thank you very much, Mr. Chairman. Thank you.
[The statement follows:]

PREPARED STATEMENT OF JOHN DEUTCH

Mr. Chairman and Members of the Committee. My name is John Deutch and I am here to present the results of the SEAB Task Force study on The Future of Nuclear Power, which I chaired. I served as Director of Energy Research and Undersecretary of the Department of Energy in the Carter Administration and, for many years I was a director of CMS Energy, a Michigan utility that operated two nuclear power plants.

Secretary Moniz charged the Task Force to describe an initiative that, if successful, would result in a revitalized U.S. nuclear industry of a scale able to deploy 5,000 to 10,000 MWe of nuclear power annually, during the time period 2030 to 2050. The Task Force report and a summary set of charts are available on the web and these materials have been provided to Subcommittee staff. In order to allow the greatest opportunity for discussion, I wish to confine my remarks to the basic thrust of the Task Force report and then to summarize very briefly its major findings and recommendations.

- If the nation wants to have a nuclear option in 2030 it must undertake now an initiative of the scale and scope such as that described by the Task Force.
- Such an initiative will take time, significant public resources, redesign of electricity markets, and sustained and skilled management.
- There is no shortcut to reestablishing a vigorous U.S. nuclear power industry that could be a major source of carbon-free electricity generation for this country and the rest of the world.

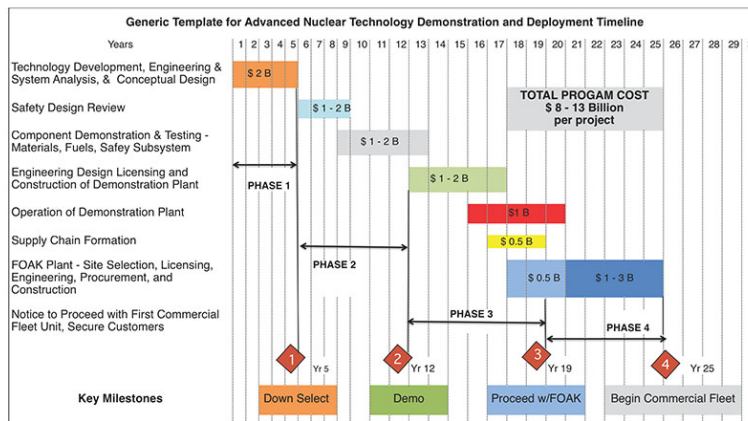
I draw your attention to following findings and recommendations of the Task Force:

- The U.S. nuclear fleet is aging and there have been a number of early retirements. The early retirements are due to the many aspects of the rules governing electricity rates and dispatch that differ in different parts of the country, which make it challenging to value base load nuclear generation appropriately. Examples include the rate structure in wholesale capacity markets, preferential dispatch rules for renewable generation, exclusion of nuclear power from renewable portfolio standards, and rates that are inadequate to assure recovery of investment. The Task Force report discusses a variety of market design measures that could overcome these obstacles. For existing plants the market obstacles need to be addressed at a State level such as has occurred in New York. However, absent market reform, additional early retirements are likely to occur and in most regions of the country there will be no real prospect for new base load generation. The Task Force believes that significant market restructuring is a prerequisite for the success of any nuclear power Initiative.
- The outlook for construction of new nuclear plants in the United States and other OECD countries is bleak primarily because of the high overnight capital cost of nuclear (\$5,000 per kWe) compared to natural gas (\$1,000 per kWe), which makes the levelized cost of electricity of nuclear generation significantly higher than the cost of natural gas generation. The cost disparity would be greatly diminished if the carbon free nature of nuclear power were recognized either by direct production payment proportional to the social cost of carbon avoided or by imposition of a carbon charge on natural gas generation emissions. Absent an economy-wide carbon emission charge the Task Force recommends a 2.7¢/kWe-hr production payment for new nuclear plants.
- The Task Force has reviewed analyses of the technical readiness of many advanced nuclear reactor systems that have experienced or are experiencing R&D either under the sponsorship of DOE or private firms. The Task Force recommends a two-part program:

New plants based on proven Light Water Reactor, LWR, technology do not need additional Federal financial support beyond the 2.7 ¢/kWe-hr production payment mentioned above. DOE assistance with NRC licensing and possibly placing early reactors on DOE or DoD sites would be appropriate and helpful.

For advanced nuclear reactors based on new technology, the Task Force recommends a four-part program to bring an advanced reactor from early concept to construction of first-of-a-kind, FOAK, commercial scale plant. The Task Force estimates this program will take up to 25 years and cost approximately \$11.5 billion. However, this estimate is highly uncertain. There is a realistic prospect of achieving a new reactor system that has significant advantages in such attributes as safety, lower cost, and water usage over present day pressurized water LWRs, but this is by no means certain. The Task Force envisions the cost to be split approximately 50—50 between the government and the private sector entity undertaking the project, with the government contribution coming in the earlier phase of the program.

- A program plan template developed by the Task Force supports the Task Force estimate of the duration and cost of an advanced nuclear reactor development:



Some observers may believe the Task Force estimate is excessively high. Note, however, the recommended program includes a \$2 billion, 5 year, Part I initial R&D period, leading to down selection of one or more advanced technologies for further development, and the Part IV 5 year period for construction of the \$3 billion FOAK commercial plant. These two stages are often not explicitly considered. An estimate that does not include these two stages would have an estimated cost and project length in the range of \$6.5 billion and roughly 15 years.

- Fuel Cycle and Waste Management.* Advanced nuclear reactors will raise different issues from LWRs for the front and back end of nuclear electricity generation. The issues depends on the advanced nuclear technology and the Task Force underscores the importance of addressing fuel cycle and waste management as part of the proposed initiative.
 - The Task Force recommends the creation of an independent quasi public corporation to manage the proposed advanced reactor initiative. The corporation should be funded by a one-time Congressional appropriation and should be exempt from Federal personnel and acquisition regulations. The independent board of directors of the corporation would be subject to Senate confirmation and an annual financial and operational report would be submitted to Congress. Such a structure is appropriate for a highly technical program that takes place over several years and requires stable funding and expert management.
- The 2012 Blue Ribbon Commission on America's Nuclear Future, co-chaired by Lee Hamilton and Brent Scowcroft, recommended the creation of a similar organization to manage their recommended program for nuclear waste. Committee staff has made the interesting suggestion of considering the creation of a single entity to manage both the advanced nuclear initiative proposed here and implementation of the Blue Ribbon Commission nuclear waste plan.
- Nuclear Licensing and Safety.* The United States Nuclear Regulatory Commission, NRC, license is the gold standard for safety. However, the NRC recent experience is only with licensing LWRs. Since the time and cost needed to obtain

a construction and operating license is large, it is important for the NRC to develop a staged approach for the licensing of advanced reactors. The Task Force believes the NRC has the authority to proceed and should do so now although more some budgetary support will be needed. Some developers may choose to construct and license new advanced reactors abroad, e.g., in China, but U.S. deployment will require full NRC review.

—*International Linkages.* For the next one to two decades, the majority of new nuclear deployments will be in Asia, especially in China and India, but also with new entrants such as United Arab Emirates, Jordan, Vietnam, and Turkey. South Korean, Russian, and Chinese firms will do most of the construction. As U.S. and OECD Europe nuclear deployments and exports decline, influence inevitably shifts to China, India, South Korea and Russia. This has important national security consequences for U.S. counter proliferation policies that could be partially reversed by the advanced nuclear initiative proposed by the Task Force. Since a nuclear accident anywhere in the world is an accident everywhere, the United States must continue to encourage safety and security in all countries.

—*Concluding Remark.* The Task Force report is unanimous. All members agree that if the nation wants to have a nuclear option in 2030 it must undertake now an initiative of the scale and scope such as that described in the report. The Task Force recognizes that there will different views on whether the proposed initiative is “practical” (i.e., whether it could gain Congressional support given alternative demands) or “necessary” (i.e., whether the future electricity system will depend on distributed generation and there will no longer be a need for base load generation).

Senator ALEXANDER. Thanks, Dr. Deutch, and thanks to you and your committee for your leadership.

THE FUTURE OF NUCLEAR POWER

We'll have a round of 5-minute questions now. And I'll begin. Just to reiterate, today we have, what, 99 reactors or about that. They produce about 20 percent of all of electricity, about 60 percent of our carbon-free electricity. I know in the region where I come from, the Tennessee Valley Authority expects to have about 40 percent of its electricity from nuclear power within a few years, and when combined that with its pollution control equipment on coal and new gas plants, it's going to be a very clean, lower cost mix of power.

You're saying, though, that your committee unanimously agrees that if we don't take some action like the one the committee recommended, that by 2030, as a country, we won't have the option of having electricity produced by nuclear power. Is that what you're saying?

Dr. DEUTCH. Precisely. Precisely. Let me say to you that when I joined the Department of Energy, six or seven nuclear plants were being fielded every year. We had four U.S. manufacturers of reactors, Babcock & Wilcox, Combustion Engineering, GE, and Westinghouse, four competing U.S. firms. That kind of capability is not going to be there in 2030 for sure, no new plants will be built in the United States unless they have very favorable regulatory findings about managing the market problems that I mentioned to you.

Senator ALEXANDER. So we would lose 20 percent of our what, we call our base load capacity, of our electricity, which is base load capacity in this case, and about 60 percent of our carbon-free. What is likely to replace that if that were not there?

Dr. DEUTCH. Natural gas. But—so let me point out to you, you, I think, said that—how many—there are 50 or so plants which are going to reach 80 years of age?

Senator ALEXANDER. By 2038.

Dr. DEUTCH. And I personally do not think it likely that the companies that manage those plants for the NRC are likely to relicense these plants from 60 to 80 years. They're the oldest plants we have. It would require quite a lot of additional investment without any attention to whether—not whether their cost of construction is cheaper, but if they actually don't have their electricity dispatched for one reason or another, they're not going to be there.

Senator ALEXANDER. Now, to reiterate again, you gave us a recommendation and said, "Unless you do something like the 25-year \$11.6 billion program to create advanced reactors, we won't have the option. If we did something like that, we were more likely to have the nuclear option."

Dr. DEUTCH. Let me pull it back one step further. Furthermore, in the first 5 years, we're proposing part 1, is the R&D phase. Meanwhile, you have these advanced light water reactors coming on. They may fit the bill, but they're going to need some help, and there is no certainty that that will be there, but there may be somebody who comes forward with a light water reactor proposal that's as good as the advanced reactor stuff. We're not married to any particular technology. We want to see the best technology developed and pushed.

CREDIT FOR CARBON-FREE ELECTRICITY GENERATION

Senator ALEXANDER. And you said that one of the difficulties—you mentioned five different difficulties in the report, but one of the difficulties is that nuclear power doesn't get credit for being carbon-free at a time when many people think carbon-free electricity is important. And if I heard you right, you said that in order to get credit that would be equal to the credit given to wind power, for example, it would be 2.7 cents per kilowatt hour.

Dr. DEUTCH. Roughly. Roughly.

Senator ALEXANDER. Roughly.

Dr. DEUTCH. The advancement tax credit.

Senator ALEXANDER. Yes.

Dr. DEUTCH. Which wind and solar—and, of course, as you know, as the penetration of wind and solar increases, there's an intermittency cost which has to be carried by somebody on the grid one way or the other.

Senator ALEXANDER. Yes.

Dr. DEUTCH. That's not included in these—

Senator ALEXANDER. So at the moment, taxpayers give wind, for example, a 2.7 cents advantage over nuclear power. Both of them are equally carbon-free.

Dr. DEUTCH. Yes. And I hope that I wouldn't be misunderstood to say I think we should take that away from wind—

Senator ALEXANDER. No, I didn't mean that. I might do that, but I understand you wouldn't.

Dr. DEUTCH. Right. But my point, I want to underscore this, carbon-free electricity generation is important in the United States

and the world, and nuclear is an essential piece of that here and elsewhere in the world.

Senator ALEXANDER. Senator Feinstein.

NUCLEAR WASTE STORAGE AND DISPOSAL

Senator FEINSTEIN. You know, John, I've known you for a long time. It's interesting to me because I look at this so differently. I look at it from the California perspective. I've been to Southern California Edison three times, seen the reactors. They have a problem with the steam generator. They buy two from a Japanese company. They're faulty. They end up having to shut down the plant. They've got 3,300 rods in spent fuel pools, no place to put them. They have a big security force. They've got a plant on a shelf above the Pacific with 6 million people living around.

Then I get a call from Tony Earley, of PG&E (Pacific Gas and Electric Company), that they're going to shut down both of their reactors because they believe they can now find cost effective clean energy to replace their 1,100 megawatts. So I have all this spent fuel sitting in metropolitan areas in an earthquake-prone State when the rim of fire is going around the Pacific with big quakes—

Dr. DEUTCH. New Zealand.

Senator FEINSTEIN. Yes. 7.8. I don't understand the push for this and the absence of a push to safely secure the waste. And we have tried and he has enormous patience with me, and so we have tried year after year to get a pilot waste. We know there are people that want to build it, a waste facility, where some of this waste—because even if Yucca went ahead, Yucca would be filled, and we have 77,000 metric tons of hot waste all over the country.

To me, until you've got a methodology to properly harbor this waste for the millennium, it's ridiculous to talk about any of this because something is going to happen one day, and it's probably on the Pacific Coast, some kind of Fukushima is going to happen, and all the probabilities of a big quake are up.

So I sit here and I listen to this, and it's like I'm in a fairy tale, that what I see in my State with four of the biggest reactors shut down, waste piling up, it makes no sense to me. And I don't understand why the industry doesn't help us push for waste facilities, and they don't.

Dr. DEUTCH. First of all, again I want to remind you, these are very sensible questions to raise about the—our task was to describe it. You may say—just the waste alone. But I want to make some remarks about that. This Congress commissioned a group of people under the chairmanship of Brent and Lee Hamilton. In 2012, they came out with a report, which was a systematic approach to managing the waste.

You know, Senator, I've got to say I'm old enough to remember Lyons, Kansas, and trying to put the wastes away. And I'll tell you, that proposal from Congressman Hamilton and General Scowcroft is an absolutely sound way to, in an orderly fashion, address all of the concerns that you properly are raising.

Senator FEINSTEIN. We had Hamilton in. We sat there with the chairs of the Authorizing Committee. We put together a nuclear waste policy for this country, which was voluntary. We went

through three chairs of the Energy Committee working on this, oh, from New Mexico, Bingaman, Wyden, and Murkowski. Murkowski worked with us all along. We've got a bill in there that the two appropriators, the two authorizers, all support, and it sits in committee, and the nuclear waste industry does nothing to help pass it. Why? I mean, I don't understand this. And we see the accidents take place? It's a kind of madness to build stuff and not be able to properly dispose of the waste.

Dr. DEUTCH. Pass the bill.

Senator FEINSTEIN. Pass the bill.

[Laughter.]

Dr. DEUTCH. The other thing—the other thing was—now, California,—may I say a word about California?

Senator FEINSTEIN. Sure.

Dr. DEUTCH. Which I know little about except that I have now two grandsons living in Palo Alto, so I have a much bigger interest in their safety.

Senator FEINSTEIN. Right.

Dr. DEUTCH. I don't know how California is going to manage without those plants, but I don't think it's so clear that it's going to be cost-free, I mean cost now in a risk sense. So I would say I don't know the head of PG&E, but I know a lot of people in California who know a lot about energy, I don't think it's going to be so easy to get that energy. Maybe—maybe—

Senator FEINSTEIN. All I can say is so far, so good.

Dr. DEUTCH. So far, so good is good, and we have to keep at it, but I think it's not at all clear how it's going to come out.

Senator FEINSTEIN. Well, I guess I plead with the industry to help us get a permanent waste facility, and one won't do it, and there have to be a number of them. You know, the WIPP (Waste Isolation Pilot Plant) accident, which is now costing in the billions of dollars, it's expensive stuff. We deal with the waste, with the plutonium and uranium processing, and it's the same kind of thing. It comes in, in the hundreds of millions and it grows to the billions of dollars to build these facilities. So somebody like me that sees what's happening in California says, why are we thinking about this if we can't provide the infrastructure to do it right?

U.S. INVOLVEMENT IN INTERNATIONAL NUCLEAR PROJECTS

Dr. DEUTCH. We have to be players because there are going to be much bigger problems with these issues in India and China, and the people who are going to be building these plants are going to be Russian firms, Japanese firms, and Chinese firms. We have to be players in that.

Senator ALEXANDER. Thank you, Senator Feinstein.

Well, Senator Feinstein and I are going to figure out how to pass that bill, so we'll—

Senator Udall.

PARIS CLIMATE AGREEMENT

Senator UDALL. Thank you so much, Mr. Chairman, and thank you both for your commitment to this and having this hearing.

Mr. Deutch, thank you. Very interesting testimony up till now, and I hope it will continue.

110 nations have ratified the Paris climate deal, which will demonstrate and initiate a need for nuclear power. Here at home, more than 360 businesses and investors support the Paris climate agreement and a low-carbon energy future for the United States.

I am very concerned about President-elect Trump's statements about withdrawing from the Paris agreement. Many nuclear companies and supporters recognize the need for nuclear energy to meet emission goals, especially in the short term, when we need dramatic movement on emissions.

Won't withdrawing from Paris have potentially negative consequences on the future of nuclear power? Could you give me a yes or no on that? And then you can expand, or course.

Dr. DEUTCH. I don't think so, Senator.

Senator UDALL. You don't think so.

Dr. DEUTCH. I don't think I can give you a yes or no answer.

Senator UDALL. Okay, go ahead.

[Laughter.]

Dr. DEUTCH. No, no, no, I don't think—I don't think it's a question which—my credentials here are to report on the Secretary of Energy's Advisory Board, not to make comments—

Senator UDALL. But the expertise that you have directly reflects on this question.

Dr. DEUTCH. Senator, I'm just not going to be able to be helpful to you on this. I mean, I would go in a completely different direction, but this is not occasion to address the question of Paris, or now they're in Morocco now, right? That's where they are, Secretary Moniz and Secretary Kerry, unless they're coming back. They've been planning for COP 22.

Senator UDALL. Right. Right.

Dr. DEUTCH. But this, I'm not the person—here I'm not the person to ask about this.

SAFELY EXTENDING EXISTING NUCLEAR PLANTS

Senator UDALL. Okay. Today, 20 percent of the U.S. electricity, and as the Chairman said, 63.3 percent of our carbon-free electricity is produced by approximately 100 light water nuclear reactors. However, many of these plants may be prematurely closing before their 2030 planned retirement, which will result in an increased proportion of energy produced by carbon-emitting sources unless other renewables, solar, wind, are able to replace the capacity of these LWRs.

What structural or statutory changes are needed to ensure that our current nuclear energy fleet remains a part of the U.S.'s carbon-free energy grid, and what structural or statutory changes are needed to enable nuclear innovation and the modernization of nuclear energy reactors?

Dr. DEUTCH. Sir, the answer is that there has to be market redesign, and that subject is dealt with in great detail, market redesign and some choices, what choices have to be made, in the report.

I would not have the—you wouldn't want to hear me talk about all of them, but let me just say that you cannot have the circumstances now with around the country, not everywhere, the Southeast United States is an exception, you cannot have the market you have giving preference to—in the dispatch of electricity to

non-base-load-generating plants so that they cannot make money even if they were cheaper.

So you have to find some solution to that. That has to be done on a State-by-State basis, and it's a very, very tough task. But otherwise, you're going to continue to have more early retirements like happened in California.

Senator UDALL. The—and I want to ask that first question in a little different way. I mean, there are many efforts both at the international level, at the State level, and at our national level to push us towards renewable sources of energy. Pulling back on those do you think would be a good idea?

Dr. DEUTCH. No.

TECHNOLOGY-NEUTRAL PRICE ON CARBON

Senator UDALL. Okay. Now, nuclear energy has a production tax credit incentive, and has had it for many, many years, as you know. However, that credit has now expired and the nuclear industry is preparing to ask Congress for new forms of support.

On the other hand, while renewable energy credits were recently extended, as you know, they are being phased out, and there is no guarantee they will be extended again. Rather than Congress debating and continuing new technology-specific tax credits, like the nuclear PTC or renewable PTCs, would the best policy be a technology-neutral price on carbon, which would promote all clean energy technologies, including nuclear renewables and carbon capture and sequestration?

Dr. DEUTCH. You say—I didn't quite get the last sentence, sir.

Senator UDALL. The last is—and it's a long one, so I'm going to say it again here, so I understand that.

[Laughter.]

Dr. DEUTCH. Thank you, sir.

Senator UDALL. Rather than Congress debating and continuing new technology-specific tax credits, that I mentioned earlier, like the nuclear PTC or renewable PTCs, would the best policy be a technology-neutral price on carbon, which would promote all clean energy technologies including nuclear, renewables, and carbon capture and sequestration?

Dr. DEUTCH. Absolutely, yes.

Senator UDALL. And that's—

Dr. DEUTCH. And I would include—I would include in that all the oil and gas drilling things as well, which gives subsidies for certain kinds of fossil fuels. The answer is yes. A single carbon charge, how the revenue is spent is critical to how it looks elsewhere.

But the answer is yes, it would be the most efficient way to do it, and that's—some members of my Task Force think that's exactly what should be done, but that's not part of our report because we are asked to frame an initiative, not to say balance it with all these things we're now discussing.

Senator UDALL. Yes. Thank you very much.

Thank you, Mr. Chairman.

Senator ALEXANDER. Thank you, Senator Udall.

Senator Shaheen.

Senator SHAHEEN. Thank you, Mr. Chairman.

And thank you, Dr. Deutch, for being here and for your work on the report. I have to say I share the issues that you raised in your testimony with respect to the importance of nuclear power as we're addressing our need to reduce carbon emissions, not only in the U.S., but throughout the world.

I also share your concerns about the importance of American technology when it comes to nuclear safety around the world. I remember talking to one of our engineers from the Seabrook Nuclear Power Plant in New Hampshire, who relayed to me what he was doing with Russia after Chernobyl in an effort to try and address safety there.

So I think those are very important and very relevant as we think about our policy. And I'm disappointed, as you've heard from several of the people here, that—I served on the Energy Committee under Chairman Bingaman when we produced an energy bill that would have addressed nuclear power in the future. That never made it to the floor. We have another bill that's currently being negotiated. It's not at all clear if that's going to make it out of Congress. That also addresses the future of nuclear power in this country. So I think we have not been responsive in the way that we should in order to address the future challenges.

In New England, 30 percent of our total electricity comes from nuclear power, so the retirement of nuclear generators is of particular concern. And you recommend significant reforms in the energy and electricity markets to help value the base load power that's produced by nuclear reactors.

ELECTRICITY MARKET REFORM

I wonder if you could discuss in a little more detail than you did in the response to Senator Udall what those kinds of reforms should look like, because as we look at New England's wholesale electric operator, ISO New England, I think it's a challenge that we have both now and are looking at in the future. So what kinds of things are you talking about?

Dr. DEUTCH. Thank you, Senator. Let me say that I'm not going to do as good a job as I could if I were here with some of my Task Force members who really specialize more in this than I do.

But let me just take the case of Illinois, where they closed I think two reactors because there was no way for them to dispatch the electricity. At night, wind will even bid negative prices so that they get dispatched in order to earn the 3 cents or whatever it is per kilowatt hour production payment, production tax credit, that they get.

So the fact is you have to fix that. You cannot have a situation where some sources of technology get dispatched with a favorable rate because of a government subsidy, others don't have the government subsidy, they can't—if they can't dispatch it. So that's a specific example.

Many of the States do not acknowledge the kinds of rates that need to be set given whatever dispatch rules they have so that a company can get back its investment over time. That's a negotiation between the regulatory commission and the company, but there is a balance there. It's not being met in many places.

Every State is different. So some parts of the country, like the Southeast, are much more accommodating. But without market reform of some kind, this ain't going to happen.

And again here's a situation, everybody in the committee is unanimous on this, and our Task Force is unanimous on this.

Senator SHAHEEN. Well, should FERC (Federal Energy Regulatory Commission) have a role in this? What should their role be in trying to look at this issue?

Dr. DEUTCH. I'm going to get myself into trouble, but I think, yes, I think FERC should have a much larger role in this. I guess there's a Supreme Court decision that gives them more ability to go and—but, you know, we have a long jealously guarded history of having local and regional utilities set their own rates on their own basis. But fundamentally, this does, in my mind, require more of a role for FERC, but it's another battle that I'm sure you guys would have to face.

SAFELY EXTENDING LICENSES OF EXISTING NUCLEAR PLANTS

Senator SHAHEEN. I'm almost out of time, but I also wanted to raise an issue that we're seeing in New Hampshire with the Seabrook Nuclear Power Plant because they will come up for relicensing I think in the early 2020s. And they've encountered some issues concerning concrete degradation, the ASR, alkalized silica reaction, and they have led to concerns about the safety of the plant and the relicensing process.

So is this something that the committee, looking at the future of nuclear power, has looked at? Are there—how should we address safety issues like that and—

Dr. DEUTCH. I believe Senator, that you're making exactly the same point that I tried to make earlier. When these plants turn to be 80—

Senator SHAHEEN. Well, this one is not going to be 80. It's a relatively young—

Dr. DEUTCH. But they're all going to be 80, but as they turn—as they get to be older, questions are going to be raised that would be applied—new plants would have to conform to, and now you have the question about, are you willing to make an assessment of the risk and say to them, “No, we're not going to relicense you, or you have to repair this”? And that's going to be done on a case-by-case basis by the NRC. I don't know the circumstances in Seabrook, although at one time I knew it pretty well, but I don't know it anymore. But those questions and concrete is a big deal.

Senator SHAHEEN. Thank you.

Thank you, Mr. Chairman.

Senator ALEXANDER. Thank you.

Dr. Deutch, you've been terrific with us, and it's good to have your experience and your straightforwardness here. I think I'm speaking for all of us, we thank you and your committee for your time and work, and Secretary Moniz, for impaneling you. If you have additional comments that you would like for us to consider, why, we would welcome your sending those to us after you leave.

I think it's time now to go to the second panel. So we'll excuse you and ask Dr. McKinzie and Dr. Icenhour, who I introduced earlier, to come forward.

Dr. Icenhour is the Associate Laboratory Director of the Nuclear Science and Energy Directorate at Oak Ridge National Laboratory, and Dr. McKinzie, Nuclear Program Director and Senior Scientist at Natural Resources Defense Council.

Dr. Icenhour, we'll start with you, if we may. And I'll ask each of you to summarize your testimony in about 5 minutes, if you will, which will give us time to consider—to ask questions. And Senator Feinstein has an important appointment at 4:00, so we'll conclude either by then or not long after that.

Dr. Icenhour.

STATEMENT OF DR. ALAN S. ICENHOUR, ASSOCIATE LABORATORY DIRECTOR, NUCLEAR SCIENCE AND ENGINEERING DIRECTOR, OAK RIDGE NATIONAL LABORATORY

Dr. ICENHOUR. Thank you, Chairman Alexander and Ranking Member Feinstein. I am very pleased to participate in this panel today.

At Oak Ridge National Laboratory, I'm privileged to lead a very talented group of scientists and engineers as we address scientific and technological challenges in both fission and fusion energy, radioisotopes, nuclear modeling and simulation, and nuclear security.

NUCLEAR RESEARCH AND DEVELOPMENT

Our nuclear fission R&D efforts include advanced reactor technologies, light water reactor sustainability, accident-tolerant fuels, used nuclear fuels, modeling and simulations, such as the Consortium for Advanced Simulation of Light Water Reactors, materials and extreme environments, manufacturing and maintenance technologies, and safety analysis and licensing approaches. This expertise enables broader contributions to nuclear security, safeguards, and non-proliferation related to R&D.

We are all familiar with the so-called nuclear cliff, which is the point in time when the current fleet of plants rapidly retires. So how will we replace that capacity? How can we rapidly innovate and enable affordable and reliable advanced reactor technologies?

The United States has historically led nuclear energy innovation, and I believe that we must continue to do so. Development of the next generation of reactors will provide clean, secure, and affordable energy, and will ensure that the U.S. industry is positioned to compete internationally.

Rapid deployment of advanced nuclear systems requires a science-based design and licensing approach. With contemporary science-based tools and techniques, development can be accelerated in laboratory and high-performance computing environments, and this can also accelerate licensing.

Materials used in nuclear systems directly affect economics, performance, and safety. The opportunity is at hand for a new generation of reactors that will also employ a new generation of materials.

We also have the opportunity to see into reactors as never before. Modern instrumentation and sensing techniques can optimize operations and further enhance safety. Predictive modeling and simulation tools provide a new basis for regulatory action and licensing.

Innovations can be introduced more quickly and designs can evolve on the drawing board. Recognizing the challenges ahead, we must move forward deliberately to avoid the nuclear cliff. Future U.S. policy for nuclear energy will be critical. Decisions are needed with specific goals. Rapid innovation will be essential and requires collaboration among the national laboratories, industry, and universities.

We must also leverage existing assets. For example, Oak Ridge National Laboratory has unique facilities, such as our research reactor and hot cells for the safe handling, experimentation, and analysis of nuclear materials.

ORNL (Oak Ridge National Laboratory) is working with Idaho and Argonne National Laboratories to implement the Department of Energy's Gateway for Accelerated Innovation in Nuclear, or GAIN, initiative, which is providing easier access to the technical capabilities of the national laboratories.

The timelines and economics are a hurdle for new reactor technologies, but they can be overcome through approaches such as increased use of modeling and simulation, advanced manufacturing techniques, and development of new materials.

There is a growing national interest in the deployment of advanced reactors and the associated fuel cycle, as evidenced by the number of summits, symposia, workshops, hearings, and other events focused on this. Such events reflect a collective sense of urgency. National laboratories are a vital part of meeting the challenges for the future of nuclear power.

A sustained R&D program is needed with clear long-term goals. Such program will retire technical and regulatory risk, improve economic competitiveness, develop the next generation of scientists and engineers, establish advanced facility capabilities, and address the entire fuel cycle.

We are prepared to help solve these compelling challenges, and we are partnering to enable rapid innovation. Together, we can succeed in bringing the best of our Nation's scientific understanding and engineering capabilities to bear on deploying the next generation of carbon-free nuclear energy technologies.

Thank you for the opportunity to share my thoughts with the subcommittee. I request that my written testimony be made a part of the public record. And I would be happy to answer your questions.

[The statement follows:]

PREPARED STATEMENT OF ALAN S. ICENHOUR, PH.D.

Thank you Chairman Alexander, Ranking Member Feinstein, and Members of the subcommittee. I am Dr. Alan Icenhour, Associate Laboratory Director for Nuclear Science and Engineering at the Oak Ridge National Laboratory (ORNL), and I am pleased to participate in this hearing with this distinguished panel today.

Oak Ridge National Laboratory is the largest U.S. Department of Energy (DOE) science and energy laboratory, conducting basic and applied research to deliver transformative solutions to compelling problems in energy and security. ORNL's diverse capabilities span a broad range of scientific and engineering disciplines, enabling the Laboratory to explore fundamental science challenges and to carry out the research needed to accelerate the delivery of solutions to the marketplace. ORNL supports DOE's national missions of:

—*Scientific Discovery*.—We assemble teams of experts from diverse backgrounds, equip them with powerful instruments and research facilities, and address compelling national problems;

—*Clean Energy*.—We deliver technology solutions for carbon-free energy sources such as nuclear fission/fusion and solar photovoltaics, as well as energy-efficient buildings, transportation, and manufacturing. We also study biological, environmental, and climate systems in order to advance biofuels, while exploring the impacts of all of these technologies;

—*Security*.—We develop and deploy “first-of-a-kind” science-based security technologies to make the world a safer place.

ORNL supports these missions through leadership in four major areas of science and technology:

—*Neutrons*.—We operate two of the world’s leading neutron sources that enable scientists and engineers to gain new insights into materials and biological systems;

—*Computing*.—We accelerate scientific discovery through modeling and simulation on powerful supercomputers, advance data-intensive science, and sustain U.S. leadership in high-performance computing;

—*Materials*.—We integrate basic and applied research to develop advanced materials for energy applications;

—*Nuclear*.—We advance the scientific basis for 21st century nuclear fission and fusion technologies and systems, and we produce isotopes for research, industry, and medicine.

As the Associate Laboratory Director for Nuclear Science and Engineering, I am privileged to lead a talented group of scientists and engineers as we address scientific and technological challenges in both fission and fusion energy, radioisotopes, nuclear modeling and simulation, and nuclear security. Our nuclear fission research and development (R&D) efforts span the nuclear fuel cycle and address the current fleet, as well as future reactors. These efforts include:

—advanced reactor technology development and design;

—light water reactor sustainability;

—research and development of nuclear fuels—increased accident tolerance and understanding the science of used nuclear fuel;

—modeling and simulation, including integrated multiphysics modeling, developing new physics codes, and exploring exascale applications;

—measurement and analysis of nuclear data;

—understanding the science of materials in extreme environments;

—development of new manufacturing and maintenance technologies; and

—safety analysis and licensing approaches.

The expertise we have established in these areas enables our broader contributions in the areas of nuclear security, safeguards, and nonproliferation-related R&D. As a result, ORNL in partnership with other DOE National Laboratories is well positioned for key contributions toward the R&D needed to meet our Nation’s energy policy objectives for the next generation.

We recognize that future energy demands will continue to require a mixture of sources that are closely and efficiently tailored to regional resources and needs. The shift to carbon-free energy sources also tells us that nuclear must play a role if we are to meet growing needs, particularly in urban and industrial environments where the baseload demand requires the availability of reliable, large-scale electricity production. As we transition toward a clean-energy economy, nuclear energy must therefore continue to be a meaningful and sustained component of the overall U.S. energy balance.

ORNL SUPPORTS NUCLEAR POWER AS A CONTINUED CARBON-FREE ENERGY SOURCE

Nuclear energy is the largest clean-air energy source in the U.S. and the only such source that produces large amounts of electricity around the clock. It is a secure source that is not subject to changing weather conditions, unpredictable fuel cost fluctuations, or dependence on foreign suppliers. Nuclear power plants produce no air pollution and do not emit greenhouse gases. These features combine to make nuclear energy an essential part of the overall global energy system. In the U.S. alone, it already provides almost two-thirds of our emission-free generation and about 20 percent of total electricity, all while producing at a greater than 90 percent capacity factor.¹

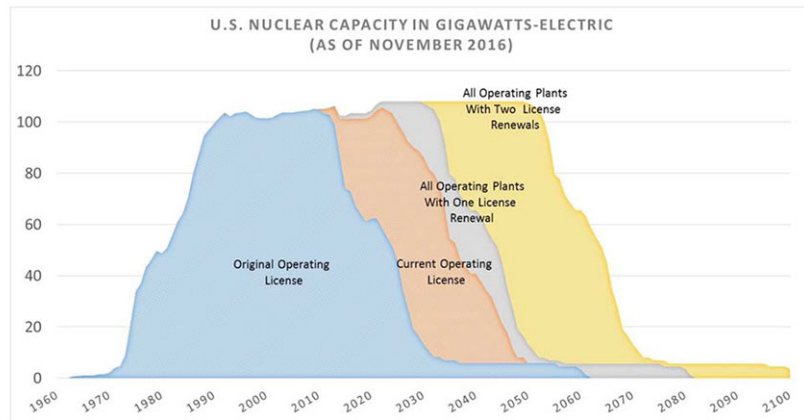
And yet many challenges remain for nuclear energy—both for the existing U.S. fleet, as well as for new reactors. The near-term future of the commercial nuclear power industry hinges upon furthering power uprates, realizing higher fuel burn-

¹Nuclear Energy Institute, 2015 statistics—In the U.S. nuclear energy provides: (a) 62.4 percent of emission-free generation; (b) 19.5 percent of electricity, and; (c) produces at a 92.2 percent capacity factor.

up, and operating the existing plants for longer lifetimes—all while dealing with market challenges, and also providing confidence in enhanced nuclear safety for both the current fleet and the next generation of nuclear power technology. In the longer term, the next generation of nuclear power technologies offers the opportunity to expand upon past successes by further improving performance, safe operations, and fuel efficiency, while contributing an even greater share of baseload electric power that is carbon-free and environmentally sound.

Avoiding the “Nuclear Cliff”

We are all familiar with the so-called “nuclear cliff,” which is the point in time when we will rapidly see retirements of the current fleet of plants as they reach the end of their operating licenses. Recently, one new plant has come on line (Watts Bar Unit 2) and four plants are in the construction phase (Vogtle 3&4 and Summer 2&3). However, six plants have also been closed since 2013,² with the most recent, Fort Calhoun, shutting down on October 24, 2016. While some remaining plants have been granted marginal capacity upratings, there are also further plants under threat of closure. From a practical perspective, nuclear electric generating capacity replacement is not yet robust and the “nuclear cliff” remains a persistent challenge.



Effect of operating life extensions on current U.S. nuclear generating capacity, depicting original operating license (blue); current operating license (brown), which reflects only the plants that have been granted a license renewal; all operating plants assumed to have one license renewal (grey); and all operating plants assumed to have two license renewals (yellow)

Effect of operating life extensions on current U.S. nuclear generating capacity, depicting original operating license (blue); current operating license (brown), which reflects only the plants that have been granted a license renewal; all operating plants assumed to have one license renewal (grey); and all operating plants assumed to have two license renewals (yellow)

The question is how will we replace that retiring capacity? How can we rapidly innovate and enable affordable and reliable advanced reactor technologies?

THE NEXT GENERATION OF NUCLEAR ENERGY

The United States has historically led nuclear energy innovation, and I believe that we must continue to do so. Nuclear energy has important impacts in terms of our national economy and security. More broadly, nuclear technology capabilities enable many other uses within science, industry, and medicine, such as high energy physics research, deep space missions, imaging, analysis, and isotope-based disease treatment. Our efforts in this area also invigorate our Science, Technology, Engi-

²The Vermont Yankee Nuclear Power Plant was shut down on December 29, 2014. Another four reactors were permanently closed in 2013 before their licenses expired: San Onofre 2 and 3 in California, Crystal River 3 in Florida, and Kewaunee in Wisconsin. The Fort Calhoun plant shut down on October 24, 2016.

neering, and Math (STEM) capabilities, as we prepare the next generation of scientists and engineers. Our common objective, across the government, academic, and industrial sectors, must be to bring the best of our Nation's scientific understanding and engineering prowess to bear on deploying the next generation of nuclear energy technologies. Meeting this objective will enable nuclear power to provide clean, secure, and affordable energy to meet growing demand, and will ensure that U.S. industry is positioned to compete internationally.

While there is a huge potential global impact by deploying advanced nuclear systems rapidly, there are also scientific questions that must be addressed in the process. By using a science-based design and licensing approach, we can improve upon history, rather than repeat it. The existing fleet of U.S. nuclear plants was developed using empirical engineering approaches. That is to say, systems were initially designed, built, and tested; designs were then marginally improved as operating experience was gained. Billions of dollars were invested in generating operating data to determine what worked best. Because of advancements in scientific capabilities, we have the opportunity to take a new approach. With contemporary science-based tools and techniques, the development phase can be rapidly accelerated in laboratory and high-performance computing environments. Similarly, there are also opportunities to accelerate the licensing phase.

The materials selected for use in nuclear systems directly affect the economics, performance, and safety of power plants. By using new materials, we can improve upon each of these important factors. The current U.S. reactor fleet relied upon alloys available from 1950s and 1960s technology which have incrementally improved. There has been a high bar for introducing new materials into reactors due to regulatory requirements that discourage design change. The opportunity is now at hand to move to a new generation of reactors that will also employ a new generation of advanced materials that can increase safety while reducing cost.

Finally, we have the opportunity to see into reactors as we could never see before. Obtaining measurements in nuclear environments is particularly difficult due to rapidly changing temperature, fluid dynamics, and radiological environments. However, the information obtained through measurements is critical to our understanding of limits to operating conditions and system lifetime. With modern instrumentation and advanced sensing techniques, a new approach can be taken to optimizing operations and further enhancing safety.

The DOE National Laboratories are the best organizations to assist in rapidly moving nuclear science and engineering toward these new horizons—because the labs rely on the science-based approach, and they field world-class facilities and capabilities. Through research, development, and demonstration of predictive modeling and simulation tools, the labs are largely displacing the old empirical approach. This provides for a new basis for regulatory action and licensing for the next generation of nuclear systems. An important outcome is that innovations can be introduced more quickly, and advanced designs can be confidently evolved “on the drawing board” without the historic need for a large investment in systems development and testing to gather experimental observations.

Extrapolating atomic-, nano-, and micro-scale processes to engineering-scale properties and performance represents a significant scientific challenge that can be met by the National Laboratories. Not only does engineering qualification of new materials take a long time, but more than 60-year service lifetimes are also difficult to demonstrate. In order to extrapolate what we can do in our laboratories with modern scientific instruments to long-term engineering performance, we must continue to improve our understanding of three key domains:

- Understanding the mechanisms of material failure enables improvements to complex alloy chemistry and permits tailoring of new materials to the challenges of operating environments;
- Understanding long-term material performance provides the basis for accurate predictive modeling and thus reduces uncertainty in life cycle analysis; and
- Accurately characterizing harsh conditions, such as radiation, high temperatures, and corrosion, further increases the fidelity and thus the reliability of our understanding of engineering performance.

While progress in modeling and simulation is rapidly advancing at the National Laboratories, the need for empirical measurements in extreme nuclear environments will never be entirely overcome. Theory advances most rapidly when validation through testing remains available. Currently, reactor and experimental instrumentation is limited. As a result, reactor operation and safety must all be designed and quantified up front. In the future, the ability to measure detailed environment conditions can be used in real time to inform operations and safety. In-core measurements during irradiation testing and new characterization tools will also improve the development process. Several related issues also need to be addressed, including:

- Survivability of sensors in extreme environments;
- Being able to place sensors in key locations;
- Transmitting data through vessels;
- Reliability of instrumentation system; and
- Being able to introduce a large number of sensors.

Recognizing the challenges ahead, we must nonetheless move forward deliberately and decisively if we are to avoid the “nuclear cliff,” which shows the rapid retirement of a large capacity in a relatively short period of time, i.e., ~100 GWe starting in the early 2030s (depending upon subsequent license extensions for some plants). This 21st century real and present threat creates a palpable sense of urgency that must be translated into action if we are to successfully modernize our nuclear power generating capacity on the needed timescale.

The Road Ahead

Recently, the Secretary of Energy Advisory Board (SEAB) assembled a Task Force that provided expert recommendations for a “Four-Phase Advanced Nuclear Reactor Program.”³ The phases proceed from technology selection through demonstration plant licensing and culminate in plant operations in preparation for private commercialization. The SEAB report points out that there are many challenges that need to be addressed—some are technology-based, while others are policy-based. The Task Force midpoint estimate is that such a four-phase program would require about 25 years. The future U.S. policy for nuclear energy will be critical. Given the challenges and timeline, decisions are needed with specific goals. It is also clear that rapid innovation will be essential.

THE VITAL ROLE OF THE NATIONAL LABORATORIES IN RAPID INNOVATION

If we are to achieve practical realization of ubiquitous carbon-free energy in the next generation of nuclear power, then rapid innovation in nuclear science and engineering is an undeniable prerequisite. While the challenges are great, our national capabilities have also been advanced as a direct result of Federal investments. We have already demonstrated some of the tools needed to accomplish rapid innovation (e.g., modeling and simulation in a high-performance computing environment), but success will require more than just advanced tooling. Rapid innovation also relies heavily on two critical factors:

- Intensive collaboration across the affected sectors—government, academia, and industry; and
- DOE National Laboratory strategic positioning to assist in systematically identifying and overcoming technical challenges through a science-based approach.

National Laboratories play an important role by providing both the expertise and facilities to work on some of the Nation’s most challenging problems. And, with respect to nuclear energy, the National Laboratories are important as we innovate. The laboratories possess unique nuclear technology expertise, ranging from very fundamental science to applications. This expertise must be preserved and further developed for the long term.

The National Laboratories are distinguished by their demonstrated ability to assemble large teams of experts from a variety of scientific and technical disciplines in order to tackle compelling national problems. They also design, build, and operate powerful scientific facilities that are available to the international research community. They work in partnership with universities and industry to train the future science and engineering workforce and transfer the results of their R&D to the marketplace.

Intensive collaboration on the next generation of nuclear science and technology will require:

Advancing Progress Through National Laboratory Partnerships.—ORNL works in close partnership with Idaho National Laboratory, Argonne National Laboratory, and other national laboratories to define and solve complex nuclear science and engineering problems—drawing upon the collective national capacity.

Advancing Technology Through Industrial Partnerships.—ORNL works closely with industry to move research into the marketplace and collaborates with other private research institutions to expand capabilities, increase the availability of facilities and expertise, and create research and development opportunities for both large institutional labs and small innovative entrepreneurs.

Advancing Science Through University Partnerships.—ORNL partners with more than 250 universities and includes several major Southeastern research

³Secretary of Energy Advisory Board, Report of the Task Force on the Future of Nuclear Power, September 22, 2016, p. 3.

universities on the UT-Battelle management team. Our core university partners—Duke, Florida State, Georgia Tech, North Carolina State, Vanderbilt, University of Virginia, and Virginia Tech, in addition to the University of Tennessee and Oak Ridge Associated Universities—ensure broad engagement of faculty and students in ORNL's science programs.

Advancing Development by Leveraging Existing Assets.—ORNL has unique facilities that enable nuclear R&D. Facilities such as our hot cells and glove box facilities allow for the safe handling, experimentation, and analysis of nuclear materials. Such assets are vital to ensure our fundamental understanding of nuclear materials and technologies and to further innovation. Additionally, we use our world-class capabilities such as the Spallation Neutron Source, the High Flux Isotope Reactor, and the Titan high-performance computer to explore materials and phenomena that are important for nuclear applications.

Using the Gateway for Accelerated Innovation in Nuclear (GAIN).—ORNL is working with Idaho National Laboratory and Argonne National Laboratory to implement the DOE's GAIN initiative, which provides the nuclear community easier access to the technical capabilities of the National Laboratories, with the goal of enhancing innovation and moving technologies closer to commercialization. GAIN enables access to nuclear and radiological facilities, testing capabilities, and computational capabilities; as well as information and data.

As reflected by GAIN, in order to deploy new reactor technologies, we must change our approach. The timelines and economics are a hurdle, but they can be overcome through new methods such as increased use of modeling and simulation, use of advanced manufacturing techniques, and development of new materials.

Modeling and Simulation has an Important Role to Play.—modeling and simulation along with data exploration have joined experiment and theory as the third and fourth pillars of science, allowing researchers who make the most of supercomputers to quickly draw conclusions from complex and copious data. Large-scale computing underpins scientific disciplines including materials science, chemistry, plasma physics, astrophysics, biology, climate research, and nuclear fission/fusion. ORNL supercomputers and support systems for data generation, analysis, visualization, and storage illuminate phenomena that are often impossible to study in a laboratory. Simulations allow virtual testing of prototypes before their actual construction and speed the development of technology solutions.

Advanced Manufacturing Techniques will Add Efficiencies.—we are also exploring new approaches to the production of qualified components for nuclear energy service, such as additive manufacturing (AM). ORNL is collaborating with equipment manufacturers and end users to advance state-of-the-art technologies and revolutionize the way products are designed and built using AM technology. Drawing on its close ties with industry and world-leading capabilities in materials development, characterization, and processing, ORNL is creating an unmatched environment for breakthroughs in AM.

Advances in Materials Science are Essential.—ORNL is a premier materials laboratory where we are researching ways to reduce the time from discovery to use. Additionally, we are exploring how to extrapolate short time experiments and measurements to the much longer times required for components in service. Scientific investigation with neutrons gives researchers unprecedented capabilities for understanding the structure and properties of materials important in biology, chemistry, physics, and engineering. ORNL provides two of the most powerful neutron science facilities in the world—the Spallation Neutron Source and the High Flux Isotope Reactor. Through materials research, scientists are discovering remarkable ways to address our energy needs.

The CASL (Consortium for Advanced Simulation of Light Water Reactors) DOE Energy Innovation Hub Experience

The ORNL experience in conceptualizing, organizing, and executing the CASL mission to provide leading edge modeling and simulation capability to improve the performance of current operating light water reactors represents a valuable model. This is because many of the rapid innovation aspects discussed above were successfully implemented in the CASL methodology. Collaboration via partnerships across the government, academic, and industrial sectors of the nuclear energy community remains a core management principle of CASL, and multiple DOE National Laboratories (ORNL, INEL, SNL, LANL) are founding partners with critical roles in addressing specific technical challenges. CASL has been a widely acknowledged success as a direct result of these practices.

CASL has been developing the Virtual Environment for Reactor Applications (VERA) software suite, which was recently recognized with an R&D 100 award. VERA simulates nuclear reactor physical phenomena using coupled multi-physics models including neutron transport, thermal-hydraulics, fuel performance, and coolant chemistry. These CASL tools are now being used in several areas for reactor analysis related to confirmation of vendor analysis tools, analysis of reactor startups, assessment of the risk of Corrosion-Related Unidentified Deposits (CRUD) Induced Power Shift (CIPS), applications to investigate fuel performance, and special studies that provide the physics simulation and fidelity to address issues that industry codes cannot. Test stands have been deployed at Westinghouse Electric Company, the Tennessee Valley Authority, and the Electric Power Research Institute to enable direct industry participation in the test and evaluation stage of CASL technologies.

Examples of CASL applications include:

- Simulation of 14 cycles (20 years) of TVA Watts Bar Unit 1 operation and simulation of Watts Bar Unit 2 startup;
- Westinghouse simulation of the AP1000™ startup and first cycle;
- CRUD and CIPS simulations by Duke Energy, AREVA, and NuScale; and
- Modeling of accident tolerant fuel designs at Westinghouse.

SETTING THE PACE FOR THE FUTURE

To further the development of advanced reactor technologies, DOE has established two projects under a Funding Opportunity Announcement (FOA), and ORNL is participating in both projects. In the advanced reactor arena, we are partners on:

- Molten Chloride Fast Reactor*: A project led by Southern Company Services, a subsidiary of Southern Company, focuses on molten chloride fast reactors (MCFRs). The effort includes ORNL, TerraPower, the Electric Power Research Institute, and Vanderbilt University. The liquid-fueled MCFR is a molten salt reactor design that offers advantages in terms of its simplicity, fuel cycle, and efficiency. Compared to other advanced reactor concepts, MCFRs could provide enhanced operational performance, safety, security, and economic value.
- Xe-100 Pebble Bed Advanced Reactor*: ORNL is also supporting a project led by X-energy to develop the fuel manufacturing methodology needed to supply the Xe-100 Pebble Bed Advanced Reactor. Partners on the project include BWX Technologies Inc., Oregon State University, Teledyne-Brown Engineering, SGL Group, and Idaho National Laboratory. The next-generation design, advanced safety features, and small footprint of the pebble bed high-temperature gas-cooled reactor will enable such a reactor to serve a wide array of community and industry needs while ensuring public safety.

Growing National Interest in Advanced Reactors

Collectively, our efforts must consider the entire fuel cycle including the supply chain. Innovation and deployment of reactors does not begin and end with just the reactor. There is clearly growing national interest in the deployment of advanced reactors and the associated fuel cycle as evidenced by the number of summits, symposia, workshops, and other events over the past several years. Last month, at ORNL we hosted our second Molten Salt Reactor Workshop, which was attended by 185 representatives from industry, academia, and government. In February 2016, we hosted the Nuclear Infrastructure Council's Advanced Reactor Technical Summit III, which brought together another 190 technologists focused on topics and methods for improving the cost and deployment timeframe of advanced reactors. Once again, industrial, academic, and government organizations were all represented.

Such events reflect the collective sense of urgency in the electric power generating community about the next steps for nuclear energy, and the National Laboratories are an important part of those next steps.

CONCLUSION

Nuclear energy faces a number of challenges and the National Laboratories play a vital role in helping to meet those challenges. A sustained R&D program is needed, with clear long-term goals. Effective R&D programs will retire technical and regulatory risk, improve economic competitiveness, develop the next generation of scientist and engineers, establish advanced facility capabilities, and address the entire fuel cycle. Rapid innovation will also be essential to achieve success on the time-scale needed to replace capacity and to enable deployment of new technologies.

ORNL is prepared to help address these compelling national challenges, and we have already begun partnering with other National Laboratories, industry, and academia to enable the rapid innovation that will be required. With your continued

support, together we can succeed in bringing the best of our Nation's scientific understanding and engineering prowess to bear on deploying the next generation of carbon-free nuclear energy technologies.

Thank you for the opportunity to share my thoughts with the Subcommittee. I request that my written testimony be made a part of the public record, and I would be happy to answer your questions.

Senator ALEXANDER. Thanks, Dr. Icenhour.
Dr. McKinzie, welcome.

STATEMENT OF DR. MATTHEW MCKINZIE, NUCLEAR PROGRAM DIRECTOR AND SENIOR SCIENTIST, NATURAL RESOURCES DEFENSE COUNCIL

Dr. MCKINZIE. Chairman Alexander, Ranking Member Feinstein, and members of the subcommittee, thank you for providing the Natural Resources Defense Council, NRDC, with this opportunity to present our views on the future of nuclear power.

NRDC is a national non-profit organization of scientists, lawyers, and environmental advocates with over 2 million members and supporters. NRDC has been engaged with nuclear energy and nuclear weapons since our founding in 1970, and NRDC maintains a nuclear program, which I direct.

FUTURE OF NUCLEAR POWER

The future of nuclear power in the United States is uncertain and faces significant challenges. As we've heard, most reactors will reach the end of their licenses and close in the decades ahead, and some are at risk of near-term shutdown.

In addition to economic challenges, difficulties for nuclear power arise from safety, security, proliferation, and nuclear waste. And the role of nuclear power as a low-carbon energy resource is being superseded by advances in energy efficiency and renewable energy technologies.

Only four reactors are currently under construction in the United States, four large AP1000 reactors, in Georgia and South Carolina. One type of small modular reactor, the NuScale SMR, may soon submit a license application to the NRC. So with many nuclear closures and few nuclear builds, the future of nuclear energy is one now of decline.

Today's hearing considers what are called advanced nuclear reactors and how they could impact the future of nuclear power and government support for their research and development.

To summarize my written testimony in a few words would be, be very cautious on advanced nuclear. First, see what results we get with our current government investment in new nuclear projects, the AP1000s, the NuScale SMR, and, importantly, prioritize unfinished business for nuclear, the waste issue, among others.

For decades, nuclear scientists and engineers have sought to develop advanced nuclear designs that reduce the amount of waste generated, that lower nuclear weapons proliferation risk, and that improve safety, but such benefits from advanced nuclear are still theoretical, and importantly, there is no evidence that advanced nuclear would be economically competitive in the future.

In our testimony, NRDC respectfully offers five recommendations for the subcommittee in consideration of the government's role in

advanced nuclear energy research and development. So I'll go through these five recommendations.

Recommendation one, and I think this was echoed a lot in today's hearing, give priority to solving the nuclear waste problem. Many thousands of tons of spent nuclear fuel must be isolated from people and from the environment for millennia. So our recommendation is site and construct a deep geologic repository using a consent-based and science-based process before spending money on advanced nuclear.

Recommendation two, wait on the construction of the AP1000s and the NuScale SMR. Assess the lessons learned from these projects for their safety, reliability, and cost before looking at an advanced nuclear demonstration plan.

Recommendation three, consistently apply a nuclear weapons proliferation test to advance nuclear designs among the energy technology choices, for the United States nuclear power is unique, and the overlaps between civilian energy technology and nuclear weapons. The risk of nuclear weapons proliferation from nuclear power can be managed, can attempt to be managed, but never eliminated. Preventing proliferation is of utmost importance for the future of nuclear energy.

Recommendation four, consider the full impacts of the nuclear fuel cycle associated with advanced reactors, including severe accidents. Many aspects of the light water reactor fuel cycle are still not worked out, including, it hasn't come up yet at this hearing, but the issue of decommissioning.

Recommendation five, get clear on the economic competitiveness for advanced nuclear early on. NRDC feels like history should teach us a caution—this was echoed in your opening statement, Senator—that funding advanced nuclear research and development for uneconomical designs can mean taxpayers are then responsible for far greater sums in the future.

To conclude, if an energy policy goal for subcommittee members is to preserve the nuclear power option in the future, then we hope you maintain a healthy dose of skepticism regarding the benefits promised by advanced nuclear technology concepts that seek taxpayer support.

Thank you.

[The statement follows:]

PREPARED STATEMENT OF MATTHEW G. MCKINZIE, PH.D.

Chairman Alexander, Ranking Member Feinstein, and members of the Subcommittee, thank you for providing the Natural Resources Defense Council, Inc. (NRDC) this opportunity to present our views on "The Future of Nuclear Power."

NRDC is a national, non-profit organization of scientists, lawyers, and environmental specialists, dedicated to protecting public health and the environment. Founded in 1970, NRDC serves more than two million members, supporters and environmental activists with offices in New York, Washington, DC, Los Angeles, San Francisco, Chicago, Bozeman, Montana, and Beijing. NRDC has been engaged with the environmental issues surrounding nuclear energy and nuclear weapons since our founding, and NRDC maintains a Nuclear Program staffed by a nuclear physicist, a nuclear engineer, a radiation health physicist and an attorney.

This testimony focuses on four topics: (1) the future of nuclear power, including NRDC recommendations to the Subcommittee regarding research, development and demonstration (RD&D) of advanced nuclear reactors; (2) deployment of small modular reactors (SMRs); (3) development and licensing of advanced nuclear reactors; and (4) nuclear energy RD&D by the U.S. Department of Energy (DOE).

THE FUTURE OF NUCLEAR POWER

Facing significant challenges, the future of nuclear power in the United States is uncertain. Today 99 reactors produce 19.5 percent of U.S. electricity; most of these reactors will reach the end of their current licenses and may close by mid-century, and approximately fifteen percent of these reactors are at risk of near-term closure due to market competition, including the possible need to replace expensive major components. Only four reactors are currently under construction in the United States. In addition to the economic challenges for nuclear power, difficulties for nuclear power arise from safety, security, proliferation and nuclear waste. The position of nuclear power as a low-carbon energy resource is being superseded by advances in energy efficiency and renewable energy technologies. A primary role of the Federal Government in energy policy is to foster energy technologies and energy systems with public benefit—prioritizing values of energy sustainability and stability of supply at low cost and without public health and environmental harms. NRDC is skeptical that nuclear power can deliver these energy values in the future.

Nevertheless, the Federal Government will continue to play primary roles in nuclear energy policy: in oversight of safety and security at operating nuclear reactors; in preventing the proliferation of nuclear weapons; and in disposing of spent nuclear fuel in one or more deep geologic repositories. Other important roles of the Federal Government include support of programs in nuclear engineering and science and in health physics at our universities and national laboratories.

The future of nuclear power could be impacted by new nuclear technologies. Today all reactors in the United States delivering electricity to the grid use low-enriched uranium as fuel with light water (i.e., water containing the natural proportions of hydrogen isotopes) serving as the coolant and neutron moderator. These U.S. light water reactors (LWRs) are of two basic designs: the Pressurized Water Reactor (PWR) and the Boiling Water Reactor (BWR), with the latter making up about one-third of operating reactors. Of the new and proposed nuclear power technologies—all as yet untested via operating U.S. prototypes—the AP1000 and the NuScale SMR are PWRs, and similarly use low enriched uranium as fuel and light water as the coolant and moderator. But there are also a host of other nuclear technology concepts being advocated for future Federal research and development support that are varied in terms of potential technological attributes.

Termed “advanced reactors,” these include, but are not limited to, the sodium-cooled fast reactor (SFR), the lead-cooled fast reactor (LFR), the gas-cooled fast reactor (GFR), a variety of molten salt reactor designs (MSRs), the high-temperature gas reactor (HTGR) and very high temperature gas reactor (VHTGR). These can be designed as large reactors or SMRs. DOE when referring to “advanced reactors” excludes LWRs. This is misleading because some of the non-LWR concepts predate LWRs and there are new LWR designs, e.g., some SMRs, that are more advanced than the current fleet of deployed LWRs. NRDC’s testimony will address selected advanced reactor concepts individually, and NRDC respectfully offers five recommendations for the Subcommittee in consideration of advanced nuclear energy research and development:

- A. Prioritize solving the nuclear waste problem over the demonstration of new nuclear technology;
- B. Wait for the construction of domestic AP1000s and a prototype SMR, and assess lessons learned from their safety, reliability and potential economic competitiveness before entertaining Federal cost sharing investments to license and construct non-LWR advanced nuclear reactor demonstration plants;
- C. Consistently apply a nuclear weapons proliferation test to advanced nuclear designs;
- D. Consider severe accident consequences and the full impacts of the nuclear fuel cycle associated with advanced nuclear reactors; and
- E. Require greater clarity on likely economic competitiveness for advanced nuclear designs earlier in the research and development cycle.

These five recommendations address the varied impacts of nuclear power and the legacies and lessons from past nuclear operations in the United States.

- A. *Prioritize solving the nuclear waste problem over the demonstration of new nuclear technology*

Nuclear power has resulted in the production of approximately 72,000 tons of spent nuclear fuel which is currently stored at operating nuclear power plants or decommissioning reactor sites at over 100 sites across the United States, and continued operation of existing U.S. nuclear reactors will result in producing another

70,000 tons for a total of over 140,000 tons by mid-century.¹ Due to high levels of radioactivity, this spent nuclear fuel must be isolated from people and the environment for millennia, and thus is an intergenerational problem. NRDC recommends to the Subcommittee that the Federal Government should give higher priority to demonstrating the geologic disposal of spent fuel and high level nuclear waste over demonstrating advanced nuclear reactors.

B. Wait for the construction of domestic AP1000s and a prototype SMR, and assess lessons learned from their safety, reliability and potential economic competitiveness before entertaining Federal cost sharing investments to license and construct non-LWR advanced nuclear reactor demonstration plants

The four nuclear power plants now under construction in the United States in Georgia and South Carolina are all AP1000s. The engineering goals of the AP1000 design are improved safety, increased operating efficiencies and smaller physical footprint than currently operating reactors. The four AP1000 construction projects are over budget and behind schedule, with the target of early next decade for first connection to the electric grid. Operator experience, capacity factors and importantly the capital cost and operation and maintenance costs of the AP1000 will remain uncertain until the completion of these projects. Given that the AP1000 represents the bulk of today's Federal, State and ratepayer investment in new nuclear power technology, the AP1000 should be carefully assessed before further significant Federal investment in advanced nuclear reactors, to determine whether the AP1000 is likely to play a role in the future of nuclear power in the United States.

Not as far along as the AP1000 is the SMR nuclear reactor concept. The Federal Government is currently supporting work to prepare one SMR design for license application at the U.S. Nuclear Regulatory Commission (NRC)—the NuScale SMR—and may support construction of a first NuScale SMR plant at Idaho National Laboratory (INL). If a first comprehensive SMR license application is submitted to the NRC in 2016, the NRC has outlined a license application review of 39 months, or possibly through 2020. But there are many unknowns for SMR licensing that impact cost and operations, for example the size of the SMR Evacuation Planning Zone, and requirements on SMR plant staffing and security. Given that the SMR represents a substantial current U.S. Government investment in new approach to commercial nuclear power, the SMR technology should be further assessed regarding its economic viability before further Federal investment in non-LWR advanced nuclear reactors, as the NuScale SMR may or may not be built.

C. Consistently apply a nuclear weapons proliferation test to advanced nuclear designs

Among energy technology choices for the United States, nuclear power is unique in that there are substantial overlaps between civilian energy technology and military applications of this technology to nuclear weapons. The risk of nuclear weapons proliferation can be managed but not eliminated. Preventing the proliferation of nuclear weapons remains a cornerstone of U.S. national security policy and is of utmost importance in considering the future of nuclear power.

Proliferation risk depends on the design of a nuclear reactor, safeguards on its operation, and the reactor's associated nuclear fuel cycle. At the front end of the nuclear fuel cycle, the capacity to enrich uranium for use as fuel in LWRs has the inherent potential to produce highly-enriched uranium for nuclear weapons. At the back end of the nuclear fuel cycle, reprocessing of spent nuclear fuel confers the technical potential to produce plutonium for nuclear weapons.

If spent nuclear fuel is not reprocessed, the fuel cycle is defined as a "once-through" or "open" nuclear fuel cycle, and if spent fuel is reprocessed (with or without reuse as reactor fuel), the nuclear fuel cycle is defined as "closed." As a general matter, the open nuclear fuel cycle represents a significantly reduced proliferation risk compared to a closed nuclear fuel cycle.

Advanced nuclear designs should reduce or at least not increase proliferation risks compared with current LWR technology. Reactor concepts that contemplate reprocessing spent fuel should not be pursued during the foreseeable future.

D. Consider severe accident consequences and the full impacts of the nuclear fuel cycle associated with advanced nuclear reactors

Full impacts of plant operations and the nuclear fuel cycle include: uranium mining, enrichment and fuel fabrication; normal nuclear plant operations and accident

¹Moving Forward with Consent-Based Siting for Nuclear Waste Facilities: Recommendations of the BPC Nuclear Waste Council, Bipartisan Policy Center, September 2016, <http://bipartisanpolicy.org/library/consent-based-siting-nuclear-waste/>.

scenarios; decommissioning of closed nuclear reactors and interim storage and final disposition of spent fuel. There are substantial aspects of the nuclear fuel cycle for current LWRs that must still be resolved. Three prominent examples are the currently inadequate U.S. regulatory frameworks for In-Situ Leach uranium mining, nuclear reactor decommissioning, and interim storage and final disposition of spent nuclear fuel.

The full life cycle impacts of operations and the nuclear fuel cycle need to be considered for advanced nuclear reactor designs early in the research and development cycle.

E. Require clarity on economic competitiveness for advanced nuclear designs early in the research and development cycle

Before significant Federal investing in research and development of advanced nuclear technologies, there should be greater clarity on economic competitiveness. The economic competitiveness of advanced nuclear will incorporate issues identified above: safety, operations and maintenance, decommissioning and waste.

As seen in recent nuclear reactor closures, the current market competitiveness of LWR technology is fragile. The price of electricity from AP1000 and SMR reactors will likely be at least as expensive or more expensive than from currently operating reactors. While the AP1000 has the relative economic benefit of larger scale, the business model for the SMR seeks to make up some of the competitive difference with the AP1000 through efficiencies in construction, operation and maintenance, and decommissioning. The price of electricity from advanced nuclear will likely be more expensive than from AP1000 or NuScale SMRs due to additional complexities of design and operations for non-light water technologies.

The Federal Government should not invest research and development funds into non-LWR advanced nuclear projects without early clarity on economic competitiveness, as ultimately this will be one important factor in whether the technology flourishes or becomes yet another failed Federal effort to force nuclear energy onto the commercial marketplace.

DEPLOYMENT OF COMMERCIAL SMALL MODULAR REACTORS

Over the past decade the status of SMRs has developed from initial interest and exploratory work, through preliminary SMR design programs by several consortia and businesses, and now to an imminent SMR design certification application to the NRC by NuScale Power and Utah Associated Municipal Power Systems (UAMPS)—the first such SMR licensing application in the United States. NuScale and UAMPS then plan to apply to the NRC for a combined construction and operation license in late 2017 or early 2018.² In February 2016 DOE issued a Site Use Permit to the UAMPS Carbon Free Power Project granting it access to the Idaho National Lab site for the purposes of identifying potential locations for the NuScale Power Plant.³ The license application to the NRC will likely reference an SMR design containing up to 12 reactor modules at the single UAMPS nuclear plant. DOE has played a substantial role in SMR research and development.

The NRC staff has developed a 39-month “optimum baseline schedule” for evaluating the SMR license,⁴ but SMR licensing may prove challenging, particularly with respect to the size of the Emergency Planning Zone (EPZ).⁵ Planning for nuclear accidents within the EPZ is one of the government’s most important responsibilities in nuclear energy policy with the goal of averting and minimizing radiation doses to people at risk from an accident. For an SMR, a smaller EPZ reduces cost and opens potential new markets near population centers, but with a corresponding loss of safety in defense in depth. Other outstanding issue for SMR licensing that also implicate SMR economics are requirements for site personnel and security, safeguards against cyber threats for digital instrumentation and controls, and decommissioning.

The 50 MWe output of a single NuScale SMR module should be compared with the approximately 100 GWe of current U.S. nuclear capacity. Replacing current U.S.

²NuScale Power, LLC and Utah Associated Municipal Power Systems Combined Response to NRC Regulatory Issue Summary 2015–07, June 17, 2015, <http://pbadupws.nrc.gov/docs/ML1517/ML15170A296.pdf>.

³U.S. Department of Energy Use Permit No. DE–NE700065, February 17, 2016, http://www.id.energy.gov/insideNEID/PDF/DOE_UAMPS%20Use%20Permit%20DE-N700065.pdf.

⁴Status of the Office of New Reactors Readiness to Review Small Modular Reactor Applications, U.S. Nuclear Regulatory Commission, August 28, 2014, <http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2014/2014-0095scv.pdf>.

⁵Ramana, M. V., Laura Berzak Hopkins, and Alexander Glaser. “Licensing small modular reactors.” *Energy* 61 (2013): 555–564.

nuclear capacity with NuScale SMRs would require approximately 2,000 NuScale reactors. The business model for the SMR includes favorable assumptions about cost savings from assembly-line manufacturing and industrial learning; however NRDC cautions members of the Subcommittee to visualize the vast scale of SMR adoption that would be required to have any impact on future U.S. nuclear energy use. While the regulatory hurdles and future operational uncertainties of the NuScale SMR project are substantial, the NuScale SMR design is better understood than advanced non-light water nuclear reactor designs.

DEVELOPMENT AND LICENSING OF ADVANCED NUCLEAR REACTORS

For decades, nuclear scientists and engineers have sought to develop reactor designs that involve one or more of the following goals: reduce the amount of nuclear waste generated, involve the production or handling of weapons-useable nuclear material, and lower the likelihood or the consequence of severe accidents. The current leading concepts for advanced non-LWRs also pursue some of these goals. While there are many non-LWR advanced nuclear technologies in early stages of development (many of them based on ideas from early in nuclear power programs), no advanced nuclear design has demonstrated any of these goals in a working prototype. These benefits of advanced nuclear are still theoretical at present. More importantly there is no evidence that any would be economically competitive with renewable energy technologies or even with the AP1000 or the NuScale SMR.

From a practical standpoint, advanced reactors are just different reactor types that must compete economically with energy resources that are currently available, including renewable energy resources. Past experiences with non-LWRs has been largely unsuccessful. Some non-LWR advanced nuclear reactor designs use fast neutrons to sustain criticality (in comparison to light water reactors that use slow or thermal neutrons), and some non-LWR designs breed and burn additional fissile material during operations. Dozens of fast breeder reactors were built and have operated for varied lengths of time since the 1950s.⁶ Because of the high costs and reliability and safety issues for fast breeders, no commercial breeder reactors have been deployed in a competitive energy market setting.

There is a consensus within the scientific community that advanced nuclear will remain a costlier nuclear technology option than LWRs until a speculative, future period of uranium scarcity not anticipated before the end of this century. For example, a 2011 study by the Massachusetts Institute of Technology “The Future of the Nuclear Fuel Cycle” concluded: “There is no shortage of uranium resources that might constrain future commitments to build new nuclear plants for much of this century at least. . . . For the next several decades, a once through fuel cycle using light water reactors (LWRs) is the preferred economic option for the U.S. and is likely to be the dominant feature of the nuclear energy system in the U.S. and elsewhere for much of this century. Improvements in light-water reactor designs to increase the efficiency of fuel resource utilization and reduce the cost of future reactor plants should be a principal research and development focus.”⁷

Some proponents of advanced nuclear reactor designs argue that these reactors coupled with a closed nuclear fuel cycle will address the nuclear waste problem. But, in reality, advanced nuclear will increase the U.S. nuclear waste burden, and the root of the nuclear waste problem is the lack of geologic disposal sites for the waste from any kind of nuclear power reactor.

Advanced reactors concepts differ substantially in design and operation, including nuclear fuel cycle aspects, from the currently licensed and operating U.S. light water reactors. There are many advanced nuclear reactor design concepts. The United States is part of the Generation IV International Forum (GIF)⁸, a collaboration among 14 countries “on the development of advanced next generation nuclear energy systems.” Members of GIF evaluated 130 advanced nuclear reactor concepts and selected six technologies for further research and development focus: gas-cooled fast reactor; lead-cooled fast reactor; molten salt reactor; super-critical water-cooled reactor; sodium-cooled fast reactor; and very high temperature reactor. But even with respect to these six categories of advanced nuclear reactor concepts, the designs are varied and utilize thermal or fast neutrons, incorporate closed and open fuel cycles, and envision reactor sizes from very small to very large. The GIF defines technology goals for advanced nuclear as: “Sustainability, economics, safety and reliability, and proliferation resistance and physical protection.” Within the GIF, the

⁶ Cochran, Thomas B., et al. “Fast breeder reactor programs: history and status.” International Panel on Fissile Materials (2010).

⁷ Kazimi, Mujid, et al. “The future of the nuclear fuel cycle.” Massachusetts Institute of Technology, Cambridge, MA (2011).

⁸ GEN IV International Forum: https://www.gen-4.org/gif/jcms/c_9260/public.

United States has expressed commitment to two of these advanced nuclear designs: the sodium-cooled fast reactor (with a closed nuclear fuel cycle) and the very high temperature reactor (with an open or closed fuel cycle).

In January of this year DOE announced⁹ a selection of two companies for a multi-year cost share of up to \$80 million in total to further develop advanced nuclear designs:

- X-energy¹⁰—partnering with BWX Technology, Oregon State University, Teledyne-Brown Engineering, SGL Group, Idaho National Laboratory, and Oak Ridge National Laboratory to solve design and fuel development challenges of the Xe-100 Pebble Bed Advanced Reactor; and
- Southern Company Services¹¹—partnering with TerraPower, Electric Power Research Institute, Vanderbilt University, and Oak Ridge National Laboratory to perform integrated effects tests and materials suitability studies to support development of the Molten Chloride Fast Reactor.

The X-energy advanced reactor concept is for a high temperature gas-cooled reactor (HTGR) design utilizing the thermal neutron spectrum and consisting of a “four-pack” of 50MWe units together generating 200MWe. HTGRs can operate with an open or closed fuel cycle.¹² A review¹³ of the history of this technology has highlighted severe hurdles this technology must overcome: “HTGRs are prone to a wide variety of small failures, including graphite dust accumulation, ingress of water or oil, and fuel failures. Some of these could be the trigger for larger failures or accidents, with more severe consequences.” The economic outlook for the Xe-100 advanced nuclear design would also face challenges in high capital cost for power plant construction, lower capacity factors and a reduced operating lifetime. The DOE Next Generation Nuclear Plant (NGNP) program tried to commercialize the HTGR¹⁴ but failed because no industrial entity was willing to cost-share with the U.S. Government on an annual 50-50 cost sharing basis. In other words, the DOE has already tried to develop this option once without success.

The Southern Company-led advanced reactor concept is for a molten salt design utilizing the fast neutron spectrum. The molten salt reactor concept was developed at Oak Ridge National Laboratory in the 1960s, but it has not been developed commercially. The Molten Chloride Fast Reactor has many technical challenges in materials and construction. The program managed by Southern is focused on benchmarking calculations with data from testing in a non-nuclear environment, for example: material corrosion rates, synthesis methods for fuel salts, salt properties, thermal hydraulics, heat capacities, and viscosities. Fundamental questions remain before costing and construction estimates can provide a sense of the possibility for licensing and commercialization of the Molten Chloride Fast Reactor. NRDC recommends scrutiny of this program with respect to several key questions: Have the corrosion problems for molten salt been sufficiently addressed with respect to the requirements of a commercial plant? Will the associated nuclear fuel cycle separate fissile material from the bulk of the salt? How will nuclear weapons materials be accounted for in proliferation safeguards?

The practical nuclear engineering and economic hurdles inherent in these technologies are such that NRDC questions whether advanced nuclear will ever be commercialized and therefore even shoulder a small fraction of energy demand in fast evolving energy markets that address the pressing needs of mitigating climate change. Furthermore, as an environmental advocacy organization, NRDC has concerns that advanced nuclear may serve as a distraction to the rapid, continued scale-up of existing, economically viable and proven solutions to the threat of climate change from wind, solar energy efficiency, and other clean sustainable energy technologies. Moreover, some advanced nuclear fuel cycles, if adopted by the United States and imitated abroad, present new safety, environmental and proliferation challenges that the world in its present state is ill-equipped to handle.

⁹ <http://www.energy.gov/articles/energy-department-announces-new-investments-advanced-nuclear-power-reactors-help-meet>.

¹⁰ <http://www.x-energy.com/>.

¹¹ <http://www.southerncompany.com/news/2016-01-15-so-nuclear-technology.cshtml>.

¹² Piet, Steven J., Samuel E. Bays, and Nick R. Soelberg. “HTGR Technology Family Assessment for a Range of Fuel Cycle Missions.” Idaho National Laboratory: Idaho Falls, ID (2010).

¹³ Ramana, M. V. “The checkered operational history of high-temperature gas-cooled reactors.” *Bulletin of the Atomic Scientists* 72.3 (2016): 171–179.

¹⁴ Kadak, Adam C. “The Status of the US High-Temperature Gas Reactors.” *Engineering* 2.1 (2016): 119–123.

RECOMMENDATIONS ABOUT NUCLEAR ENERGY RESEARCH AND DEVELOPMENT AT THE
U.S. DEPARTMENT OF ENERGY

The DOE's May 2016 draft "Vision and Strategy for the Development and Deployment of Advanced Reactors" correctly prioritizes addressing the problem of climate change;¹⁵ however in reality advanced non-light water reactor technology is today only remotely relevant to carbon mitigation due to cost, safety and design uncertainties and the very extended roll-out times that would be required. NRDC disagrees with DOE's assessment that "sustaining a substantial nuclear presence in the U.S. power mix beyond 2050 will almost certainly require the development and deployment of a new generation of advanced reactors" given current uncertainties with advanced nuclear and that performance data for the first AP1000 reactors and potentially for the first SMR is still forthcoming and central to this assessment.

In this draft vision and strategy document, DOE has stated a goal of: "By the early 2030s, at least two non-light water advanced reactor concepts would have reached technical maturity, demonstrated safety and economic benefits, and completed licensing reviews by the U.S. Nuclear Regulatory Commission (NRC) sufficient to allow construction to go forward." From NRDC's perspective this is not a reasonable goal, as it presumes the technical need for and economic competitiveness of advanced nuclear which are far from being demonstrated. Instead, DOE's role for advanced nuclear should be small investments in research and development in areas such as computer modeling and materials science that also have applications for nuclear safety, for nuclear non-proliferation and for non-nuclear energy technologies, such as the use of molten salt for energy storage in renewable generation.

Advanced nuclear reactor designs with their associated nuclear fuel cycles require vigilant attention to nuclear weapons proliferation. NRDC recommends that DOE commission a "red team" study that would seek to exploit the proliferation potential of advanced nuclear energy options, looking at different scenarios —proliferation intent at time of adoption of the advanced nuclear technology, sudden breakout to nuclear weapons capability from a civilian nuclear power program that uses advanced nuclear reactors, or a gradual accumulation of nuclear weapons materials and infrastructure over decades of advanced nuclear power generation leading to establishment of a nuclear arsenal. The nuclear weapons design capacities at the U.S. National Laboratories would be a resource to draw on for such a red team study.

Nuclear energy research and development at the DOE is the spending of taxpayers' money. Given this fact, it is important to consider these DOE programs in the context of substantial existing Federal subsidies for nuclear energy. A 2011 study published by the Union of Concerned Scientists¹⁶ found that: "subsidies to the nuclear fuel cycle have often exceeded the value of the power produced. This means that buying power on the open market and giving it away for free would have been less costly than subsidizing the construction and operation of nuclear power plants." Thus, government support for nuclear energy is very broad, and not limited to research and development. NRDC recommends this history should invoke caution from the Subcommittee, as approval of funding advanced nuclear research and development for uneconomical designs can mean taxpayers are then responsible for far greater sums in the future.

CONCLUSION

The future of nuclear energy in the United States is uncertain and challenged. In addition to economic challenges for nuclear power, difficulties arise from economics, safety, security, proliferation and nuclear waste, and the value of nuclear power as a low-carbon energy resource is being superseded by advances in energy efficiency and renewable energy technologies.

In consideration of DOE research and development support for advanced nuclear, NRDC respectfully offers five recommendations to the Subcommittee: prioritize solving the nuclear waste problem; assess the prototype AP1000 and SMR before considering further Federal investment in advanced nuclear; consistently apply a nuclear weapons proliferation test to advanced nuclear designs; consider the full impacts of severe accidents and the nuclear fuel cycle associated with advanced nuclear reactors; and require greater clarity on the likely economic competitiveness of advanced nuclear designs early in the research and development cycle.

¹⁵ <http://www.energy.gov/ne/downloads/draft-vision-and-strategy-development-and-deployment-advanced-reactors>.

¹⁶ Koplow, Douglas N. Nuclear power: Still not viable without subsidies. Union of Concerned Scientists, 2011. http://www.ucsusa.org/sites/default/files/legacy/assets/documents/nuclear_power/nuclear_subsidies_report.pdf.

If a public policy goal for Subcommittee members is to preserve the nuclear power option for the United States in the future, NRDC recommends maintaining a healthy dose of skepticism regarding the putative benefits promised by the numerous advanced nuclear technology concepts seeking taxpayer support for their development.

Senator ALEXANDER. Thank you, Dr. McKinzie.

Senator FEINSTEIN.

Senator FEINSTEIN. Thank you, Mr. Chairman.

NUCLEAR WASTE STORAGE AND DISPOSAL

Mr. McKinzie, you know, it's interesting because we have no nuclear waste policy in this country. And as such, we pile up fines, I think it's \$20 million a year, which are in the hundreds of millions of dollars, and yet still fail to act. You've looked at this. Why does that happen? I mean, why wouldn't the industry want a nuclear waste policy? Why wouldn't they want a nuclear policy, a process by which this—we've debated it, we've discussed it, and come to the conclusion, you know, that it has to be practical, it has to be voluntary, States have to want it.

We have one in New Mexico, WIPP, the people of WIPP and around it want it, they take great pride in it. A stupid accident for even the most sophisticated agency, Los Alamos, who contracts out the kitty litter, and they use the wrong kitty litter, and it explodes.

So it's very hard for some of us to conceive of a future that's properly carried out. And now that these SMRs are being proposed, I am told that the only way they're cost—they're economically cost efficient is if they're grouped together. So if you're going to put four 300- or 400-megawatt reactors in one place, you still have to deal with the waste. How do you do that?

So I guess I've really developed a very jaundiced view about the practicality in this country and the ability—I mean I was alerted by what Senator Shaheen said about the concrete. And without going into it, John Deutch said, well, that's a serious problem. Now I'll go and look and find out exactly what it is.

So if either of you have some comments to make, because I think our first responsibility is safety to the public, is to see that these things are secure, that the waste is secure, that they are as functional and efficient and well built as they possibly can be, sited appropriately, run scrupulously, and that's difficult to have happen.

And so it doesn't surprise me that people coming up or companies coming up for relicensing may opt not to go ahead.

Dr. MCKINZIE. I would—if I could be very candid on why I think industry hasn't supported a nuclear waste solution in a vigorous way, I think it would be because the current waste situation is consistent with the industry's business model, storage of spent nuclear fuel, mostly in wet pools, some in dry cask, at reactor site. That's fine with the business model.

NRDC objects to the NRC finding that long-term storage of spent nuclear fuel in wet pools, in densely packed wet pools, doesn't represent an incredible danger, an incredible risk, but yet that is tolerated by the regulator. And so there just is inertia in the industry.

Senator FEINSTEIN. Well, I think, and somebody correct me if I'm wrong, but I believe you store them for 5 to 7 years, and then they should be removed from the spent fuel pool, and they should be put

in dry casks, hopefully transportation dry casks, so that they can be moved then to a permanent waste facility, which we don't have.

And so I can only speak for California, which I know these things are just stacking up. And, yes, there's a very real danger in spent fuel pools. If the water disappears, if the pool is fragmented by an earthquake, and you have all these hot rods, 3,300, piled up, it's a big problem.

So—but no one seems to care. That's what really bothers me. Nobody seems to care.

Dr. MCKINZIE. It's a very difficult problem. The NRDC advocates for a consent-based and science-based approach on deep geologic repositories. That also includes authority at the State level for regulating radioactive materials. That's not there. That is a component of WIPP, and we believe why WIPP was able to go forward in the first place, but we believe that State authority in regulating radioactive materials with respect to repository is a key element to include.

Senator FEINSTEIN. Thank you.

Thank you, Mr. Chairman.

SAFETY RECORD OF NUCLEAR POWER

Senator ALEXANDER. Thank you, Senator Feinstein.

Thanks to both of you. I'll have just a couple of comments. I would not want people to leave this hearing without a different view being expressed about the safety of nuclear power. There has never been a death in connection with the commercial operation of nuclear reactors in the United States since they began. There's never been a death attributable to reactors in the Navy since the 1950s, when they began. The only most celebrated accident we had in the United States was Three Mile Island in 1979, and despite years of testing of everybody in the area, no one was hurt.

So based on the safety record, no other form of energy has a better safety record. And the Nuclear Regulatory Commission, which has extensive careful regulation, has determined that the used fuel is safely stored for many years in the places where it is, which is onsite.

NUCLEAR WASTE STORAGE AND DISPOSAL

And I agree that we need to move it, and I would like to get it out of California, too, but we have a place to put it, and the place is Yucca Mountain in Nevada, and the law says that's where it should go, and the courts say that's what the law says, and the scientists have said that it's safe there for a million years. And Yucca Mountain is large enough to accept all of the used nuclear fuel that we have stored onsite in the United States today. So we have a stalemate in the Congress.

The reason we haven't passed the legislation Senator Feinstein and I would like to pass is because we take the position that we should move ahead on all tracks at once, and if we get stuck on one, we should still—namely, Yucca—we should continue to move on the others. Some of those who strongly support Yucca Mountain say, well, if you don't move on Yucca, you're not going to move on anything.

Well, we've got to solve that. That's our responsibility really. The help of others would support our position, that's true, but that's our responsibility to work out, and we're going to continue to try to do that.

ADVANCED NUCLEAR REACTORS

Dr. Icenhour, I just have maybe one or two questions. You heard the testimony about the proposal for two advanced reactors to be licensed and ready for construction in the 2030s from Dr. Deutch's report. Do you think the goal is achievable? And if so, what do you think it will take to accomplish it?

Dr. ICENHOUR. Yes, Senator, I do believe that is achievable. And one of the things I reflect on, I like history also, as Senator Feinstein said, and when I drive into Oak Ridge National Laboratory, I drive past the graphite reactor, and that's a lesson in history of what this country can do, a reactor that was built in 9 months, went critical in November 1943. And that just reminds me of what we can do when we decide to do something. And so the question is, how do we get there?

We have to, first of all, decide to do it and move forward, much like Mr. Deutch was saying. We have to decide we're going to do this. We have to set clear goals. We have to have focused effort, focused R&D, that will help move us along the way. And it will take a public-private partnership to do this.

And then the final element I would add is along the way we have to continue to work with NRC to have the appropriate regulatory framework in place.

ADVANCED MODELING AND SIMULATION

Senator ALEXANDER. All right. Dr. Icenhour, you talked about the big computers at Oak Ridge and the work you're doing on modeling and simulation. As we talk about relicensing, taking, say, Seabrook maybe from 40 years to 60 years, or taking some of the existing reactors from 60 years to 80 years, which the Nuclear Regulatory Commission is considering, how can the supercomputers you work with help with determining whether it's safe and appropriate to do that or not?

Dr. ICENHOUR. Well, one example of that, Senator, is, of course, the Consortium for Advanced Simulation of Light Water Reactors, or CASL, which has developed a very high-fidelity model of a nuclear reactor, and so we're able to understand that very clearly what's happening with the reactor and as changes occur.

And so it's the use of advanced modeling and simulation coupled with experimental data that can help enable the understanding and help inform the basis for moving forward for life extensions.

NUCLEAR POWER AND CLIMATE CHANGE

Senator ALEXANDER. Dr. McKinzie, you work for a well-recognized group, the Natural Resources Defense Council. I would assume you and the Council are concerned about climate change?

Dr. MCKINZIE. Yes, we are.

Senator ALEXANDER. Dr. Deutch said his committee was unanimous that if we didn't take some action, that by 2030, we wouldn't

have nuclear power option going forward in the United States, so we would lose 20 percent of our electricity and 60 percent of our carbon-free electricity. Do you think that helps us deal with climate change?

Dr. MCKINZIE. I would—I question the 2030 as a cliff where all of that power suddenly turns off. It will be more like a ramp down in power as different units reach different ages and—

Senator ALEXANDER. Well, this testimony, unanimous by a widely divergent committee, was that if we hadn't acted by 2030, the option would be gone, which I guess means that by then, we wouldn't have a way to continue it as, over the next 20 years, the rest of the reactors closed.

Dr. MCKINZIE. Addressing climate change is a critical problem that requires a transformation in how our country, how the world, generates and consumes energy. In the United States right now, we have a mix—

Senator ALEXANDER. Well, wait a minute. My question is, do you think that we—that it helps dealing with climate change to lose the nuclear option by 2030, as his Task Force unanimously said would happen?

Dr. MCKINZIE. I'm a skeptic that nuclear will be able to deliver the energy, the low-carbon energy that we need to address climate change—

Senator ALEXANDER. Well, but today it produces 60 percent of our carbon-free electricity.

Dr. MCKINZIE. But it has an uncertain future.

Senator ALEXANDER. Well, but how much of our carbon-free electricity does wind power produce today?

Dr. MCKINZIE. Oh, wind power produces less carbon-free energy than nuclear, but renewable energy, energy efficiency, it has really made incredible advances recently and showing itself as a lower cost option than nuclear for addressing climate change, and I believe that progress will continue.

Senator ALEXANDER. So you would be comfortable with losing the nuclear option in terms of our country's ability to deal with climate change.

Dr. MCKINZIE. I am uncomfortable with unresolved problems for nuclear energy, unsolved problems. I believe that pragmatically nuclear will continue at a lower level into the future. I don't imagine it vanishing. We have the four AP1000 reactors under construction.

So I think that a scenario in which everything is gone by 2030 is perhaps too negative for nuclear energy, but I'm a skeptic that nuclear can continue to contribute at its current level.

Senator ALEXANDER. What would replace it?

Dr. MCKINZIE. Well, the Department of Energy's own national laboratories have seen a scenario where renewable energy can be the dominant source of clean energy in the future.

Senator ALEXANDER. Meaning windmills.

Dr. MCKINZIE. Solar, wind—

Senator ALEXANDER. Solar is today less than 1 percent of our electricity, right?

Dr. MCKINZIE. That's correct, Senator.

Senator ALEXANDER. And wind is about 3 or 4 percent of our electricity.

Dr. MCKINZIE. But the recent growth has been extraordinary, and that trend we believe will continue.

Senator ALEXANDER. And the wind is available when the wind blows, and the solar is available when the sun shines.

Dr. MCKINZIE. There is an issue of base load versus non-base-load generation to contend with. I would say that our—the transmission grid is evolving in time and changing in time and adapting to a variable generation as well as there will probably be advances in storage.

I think that nuclear will probably play a role in the future. I'm not sure how large. And I do know there are longstanding problems to solve first.

YUCCA MOUNTAIN

Senator ALEXANDER. So you do agree that finding a way to store used nuclear fuel, I believe it was your testimony, is an urgent—

Dr. MCKINZIE. Absolutely.

Senator ALEXANDER. So you support opening Yucca Mountain?

Dr. MCKINZIE. No, NRDC does not support opening—

Senator ALEXANDER. Why not? The law says it should, the court says the law says that, and the scientists say it's safe for a million years there.

Dr. MCKINZIE. Well, the process of restarting the Yucca Mountain project would begin with the license application, and resolving over 200 contentions, new and significant information that may actually necessitate starting from scratch in terms of the license—

Senator ALEXANDER. So you think we can open another repository more rapidly than we could complete Yucca Mountain?

Dr. MCKINZIE. We believe that Yucca Mountain will likely fail, and so we do need to go back to basics in—

Senator ALEXANDER. But do you believe we can open—so you—it would fail because groups like yours don't support doing it even though the science says it's safe there for a million years, and the law says we should do it.

Dr. MCKINZIE. We don't believe it would be able to get through the licensing process. NRDC is not party to the licensing process.

Senator ALEXANDER. Yucca Mountain would be large enough to hold all the stored nuclear fuel in the country that we have today, correct?

Dr. MCKINZIE. Modifications to Yucca Mountain are envisioned that would enable it to store more fuel and require it to include things like titanium drip shields to prevent migration of the waste.

Senator ALEXANDER. Wait just a minute. The Nuclear Regulatory Commission has testified here that Yucca Mountain is large enough to hold all of the stored—all of the nuclear fuel that's currently stored at the approximately 100 reactors in the country. You disagree with that?

Dr. MCKINZIE. No, I don't disagree with that, if you're talking about the 77,000 tons that are stored currently. But the United States will generate again as much between now and mid-century.

Senator ALEXANDER. Right. And so my view is that we should open Yucca Mountain, put the fuel we have there, move it out of California, other places where it is, and open new repositories, maybe a private repository, and solve our stalemate.

Well, in any event, we've had a terrific wide range of views here today, both from the Senators and from expert witnesses.

Dr. McKinzie, Dr. Icenhour, thank you both so much for being a part of our discussion.

The hearing record will remain open for 5 days. All statements submitted by witnesses and Senators will be included in the record. The subcommittee requests all responses for the record be provided within 30 days of receipt.

If either of you have something you would like for us to consider that you didn't have a chance to say today or when you go home you wish you had said, if you'll send it to us, we'll distribute it to the other Senators.

CONCLUSION OF HEARINGS

Senator ALEXANDER. We thank you very much for taking your time to be here.

The subcommittee stands adjourned.

[Whereupon, at 4:02 p.m., Wednesday, November 16, the hearings were concluded, and the subcommittee was recessed, to reconvene subject to the call of the Chair.]