Testimony

Dr. Peter B. Lyons

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

Preserving and Expanding Clean, Reliable Nuclear Power:
U.S. Commercial Nuclear Reactor Performance Trends and Safety Initiatives

Room 406
Dirksen Senate Office Building
November 13, 2019

Chairman Barrasso and Ranking Member Carper, it is an honor to testify in this hearing of your U.S. Senate Committee on Environment and Public Works on a subject that has been the focus of my professional activities for at least three decades.

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

Since my retirement in 2015, I have been involved in many activities related to preserving the vital resource represented by the nation's nuclear power plants. I served as co-chairman of the American Nuclear Society's Special Committee on Nuclear in the States. We provided assistance in New York and Illinois, as they were some of the first states to consider development of legislative initiatives to prevent potential nuclear plant closures. I accepted an invitation from U.S. Energy Secretary Rick Perry to serve on his Nuclear Energy Advisory Committee, where I also serve as Co-chairman of the Subcommittee on the Existing Fleet. Among other responsibilities, I've been elected to the Board of Directors of the American Nuclear Society, serve on the Advocacy Board of Nuclear Matters, and serve as Chairman of the Board of Directors of the Consortium for Advanced Simulation of Light Water Reactors (CASL).

U.S. Nuclear Plants: A Vital National Resource

Our nuclear power plants represent a vital resource for the nation. They are by far the most resilient component of our nation's electrical grid, as has been proven in some of the extreme

weather events in the last few years. For example, in the January 2019 polar vortex, all of Exelon's Pennsylvania nuclear plants operated at full power while wind chill factors went as low as -35° F. As former DHS Secretary and Pennsylvania Governor Tom Ridge noted in a 2017 editorial, "The goal of grid resilience cannot be met without nuclear power."

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

The carbon-free generation of electricity by nuclear plants is critical as clean air and mitigation of climate change are increasingly valued. In fact, nuclear plants provide more than half of the nation's emissions-free electricity. An interesting statement from Secretary Perry at a conference in March was: "I don't know how anybody who cares about the climate can't be for nuclear energy." The role for nuclear energy in contributing to the climate change challenge is widely recognized, with recent statements ranging from The Nature Conservancy to the Union of Concerned Scientists, to the International Energy Agency and the World Resources Institute. As Senator Lamar Alexander recently noted, "If you want clean energy, nuclear ought to be the first step."

Nuclear power demonstrates impressive economics. In 2018, the average generation cost for U.S. nuclear power plants was about 3.2 cents per kWh. That figure results from a continued focus on improved economics. For example, by comparison, in 2012 the average cost for U.S. nuclear power was 4.2 cents per kWh. (However, these impressive averages obscure some details, such as higher costs for operating single-unit sites as opposed to multi-unit sites.)

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

In addition, the national security benefits of our nuclear power plants can not be understated. Secretary Perry has stated that "Energy security is national security." Certainly, the reliability and resilience contributed by nuclear power to our national grid are fundamental to our energy

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

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

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

The risk of losing U.S. nuclear power capabilities.

Since 2014, the U.S. has seen nine reactors close prematurely. These units provided about 55 million megawatt-hours of clean generation each year, more than 80% of all the solar electricity produced by U.S. utilities in 2018. The economic pressures behind these closures have not abated. Low cost natural gas unleashed by fracking, anemic electricity demand growth, and policies that are solely designed to deploy a class of technologies that excludes nuclear energy have continued to erode the economic viability of many nuclear plants, particularly in wholesale markets. Owners of eight additional units have announced their pending closures. State-level

policies have proven effective in preserving a large portion of the U.S. generating fleet. Fourteen units with 14,000 megawatts of capacity – annually producing 114 million megawatt-hours of clean electricity – remain in operation as a result of state actions. (This would be the sixth largest nuclear producer in the world if it were a separate fleet.) But state actions can not substitute for a strong federal policy that protects our nation's nuclear power plants.

While still further economies are being sought by the industry, the situation remains complicated by the very low generation costs for natural gas and by the fact that intermittent solar and wind operate with zero fuel cost, solar construction costs are reduced by federal investment tax credits, and wind farms (and some solar installations) earn federal production tax credits whenever they operate. The federal tax credits and other policy incentives provided to solar and wind mean that they can profitably run even when their abundance in some locations and at some times of the day leads to negative electricity prices. Obviously, no energy source that purchases its fuel can compete at negative pricing. But since consumers need electricity when the sun and wind do not cooperate, other sources of power must be standing by to provide power as needed.

One topic under study by the commercial industry is the potential applicability of Accident Tolerant Fuels. These fuels, which have now been introduced in small tests in several operating reactors, have the potential to positively impact both safety and economics of the nuclear industry. Many tests are currently underway within industry with assistance from several of our DOE national laboratories, and some vendors may be in a position within a very few years of asking the NRC for permission to utilize these new advances. The NRC will be challenged to respond to these requests in a timely manner and the use of risk-informed regulatory approaches, that I will discuss later, may prove to be important in their evaluations of these fuel improvements.

The continued erosion of our current fleet should be of immense concerns in Congress. In my work with the Secretary's Nuclear Energy Advisory Committee, that Committee recently endorsed a key statement, namely that: **Policy changes are necessary to ensure survival of the existing fleet of U.S. commercial nuclear plants. Continued early shutdowns of operating plants are jeopardizing the ENTIRE domestic commercial nuclear industry and threaten to have extremely severe repercussions on national security and the integrity of the national electricity grid. Without policy changes, reductions in operating costs and improved efficiencies utilizing advances in technology will not be sufficient to address the crisis in short-term economic sustainability."** Thus, my concern that Congress should develop policies that enable a strong domestic nuclear industry to thrive.

Opportunities for New Nuclear Plant Construction.

The subject of your Hearing includes expansion of nuclear power in addition to preserving our existing capabilities - a topic that is vital to the future of nuclear power in the country. (However, I must note that realization of any new designs depends on preserving the existing fleet so that the nation maintains a vibrant nuclear industry.) Many U.S. companies are exploring a wide range of advanced designs; estimates of the number of such companies range up to about 60 with

designs ranging from GW-class reactors to extremely small micro reactors with powers below 10 MW. Some of these advanced designs use light water coolants, in particular the new generation of small modular reactors that offer significant improvements in key safety and performance parameters over existing light water designs. Other advanced designs are exploring non-light water coolants that may enable still further advantages.

Many of these advanced reactors, including the Versatile Test Reactor (VTR) that Congress has funded, will depend on fuels with higher enrichments than current used in the industry. Some will need at least High Assay Low Enriched Uranium or HALEU and some, like the VTR, would strongly benefit from use of plutonium-based fuels. In addition, some requirements for HALEU can be met with blends of plutonium and low-enriched or natural uranium. I must note that I find it most perplexing that the current and past Administrations plan to dispose of 34 tons of weapons-grade plutonium, as required in the Plutonium Management and Disposition Agreement signed with Russia in 2000, by burying it in the Waste Isolation Pilot Plant (WIPP) in New Mexico, especially when this exact approach was rejected by the Russians in the original negotiations. In my view, this was a very poor decision and deprives the nation from gaining significant benefits from the taxpayer resources invested in making the plutonium in the first place. I also believe that it could jeopardize the licensing basis for WIPP, which is certainly not licensed for such disposition.

Deployment of future reactors will continue to be plagued by the nation's failure to deal with its used fuel and the continued absence of a credible used fuel management policy will undermine future new reactors. Other nations, like Finland, Sweden, and France, are far ahead of the U.S. with well established policies and underground repositories very close to operation. In my view, the nation can continue to try to open Yucca Mountain, despite the simple facts that it has poor geology (and because of that it will be unnecessarily expensive to build) and is constantly under attack in Nevada, or the U.S. could use the consent-based approach to both interim storage and a repository recommended by the Blue Ribbon Commission, on which my mentor Senator Pete Domenici was a key participant, or we could explore reprocessing. In my view, it is long past time to explore the consent-based approach to siting a repository and I also think it is past time to better understand how reprocessing, as well as other emerging technologies like deep boreholes, might improve our nation's management of used fuel.

As these advanced designs move towards commercialization, they will need to progress through review by the Nuclear Regulatory Commission. And all these designs face the challenge that their operational principles depart significantly from the current generation of light water reactors, with which the NRC has extensive licensing experience, and all would be impossible to license if the NRC relies on the deterministic approach to licensing that now forms the core of the NRC regulations.

The Role of NRC's Continued Learning and Regulatory Evolution

This brings me to two important points regarding the NRC. First the NRC is, and has always been, a learning organization. The importance of this fact was brought home to the fledgling NRC back in the days of Three Mile Island (TMI), when the NRC was very deficient in its ability to respond to that crisis. As the President's Commission on that accident noted, "“With its

present organization, staff, and attitudes, the NRC is unable to fulfill its responsibility for providing an acceptable level of safety for nuclear power plants."

From that inauspicious beginning, the NRC accelerated its learning process, and, throughout its subsequent history, it has emphasized that it will learn and progress as additional knowledge is gained. As just one example, the precise issue that caused TMI had already happened at multiple plants, some abroad and some in the United States; in those previous cases, the operators realized the issue and responded correctly. But back then, there was no mechanism to share operational experiences, a deficiency that was swiftly corrected by the NRC after TMI and an early lesson in the learning process that has shaped the NRC of today.

I might note that improvements at the NRC were not the only outcome of TMI. The Institute for Nuclear Power Operations, INPO, was formed as another direct response by industry. Today, INPO and NRC are two separate, but cooperative, institutions that work to assure the safety of U.S. nuclear power plants. At the NRC, I gained tremendous respect for INPO, and I strongly believe that INPO shares in the credit for the achievements of the U.S. nuclear industry. And it's interesting to note that enhanced focus on safety after TMI has also led to substantial improvements in the output of U.S. nuclear plants. At the time of TMI, capacity factors for U.S. plants were around 50-60%, but for many years now those factors are well over 90%. That means that more clean reliable power has been generated from these plants, which has helped the nation at the same time that it boosted the safety and profitability of the industry.

In addition to the cooperation between NRC and INPO, another important cooperative arrangement involving the NRC is their interactions with the Department of Energy. During the time I was the Assistant Secretary, I used to meet regularly with the NRC Chairman, and we worked together to increase the cooperation between the organizations, while still recognizing their absolutely separate and distinct responsibilities. We found many cases where data that DOE acquired was invaluable to the NRC. Of course, the data had to be acquired with suitable quality controls before the NRC could use it, and the NRC used the data to frame regulatory positions while the DOE would make the data available to industry for their own use in developing new capabilities. But this cooperation today is essential to both the regulator and to industry.

The Consortium for Advanced Simulation of Light Water Reactors, or CASL, is a good example of this cooperation. In CASL, the DOE has developed a suite of reactor simulation codes that use modern high-performance computing. These codes have been made available to the NRC and, of course, to U.S. industry, even to the point where CASL is being studied by the NRC to further evaluate potential use of CASL codes. My view is that if future evolution leads to both industry and the regulator using common, well verified, modern computer codes, again for their own specific purposes, this represents a win-win for the country and a sound investment of the quarter billion dollars of taxpayer resources invested over ten years in CASL.

Other examples of this cooperation will be essential in the near future. For example, as industry moves to utilize the Accident Tolerant Fuels, which I mentioned earlier, data obtained from DOE-funded programs will underpin licensing cases. Similarly, for non-light water reactors the DOE has decades of data from experiments with alternative coolants; it is essential that DOE and NRC work together to provide NRC with the data they will need to reach regulatory decisions.

A key area of evolution at the NRC involves risk-informed regulation. This is hardly a new topic, in fact, it could be argued that the current, more deterministic set of regulations evolved from risk-informed evaluations for the current generation of commercial plants. But as the NRC is faced with licensing requests for advanced concepts, many of the current deterministic regulations must be re-examined for their applicability and, in these evaluations, I believe it is vital that risk-informed judgments be reached.

Risk-informed regulation was discussed extensively even when I worked on Senate Staff around the year 2000, and the NRC has been moving in that direction for at least two decades. But the sheer number of new concepts that the NRC will face in the next few years will place even stronger needs to emphasize decisions which are risk informed.

The use of risk-informed principles is already evident in much of the current NRC work. For example, when the NuScale SMR was judged by the NRC not to need any safety grade power, i.e., that it could withstand a complete loss of station power and didn't even require backup emergency diesels, that was an example of a risk-informed decision that departed from the NRC's deterministic approaches. In the case of NuScale, since they don't use pumps in normal or off-normal operation, in complete contrast to every operating commercial reactor in the world, the NRC approached the challenge by analyzing any potential risk and reaching a risk-informed decision. Many more similar cases are pending at the NRC involving NuScale, wherein the existing deterministic regulations just don't make much sense for their new concepts. I mentioned Accident Tolerant Fuels and non-light water coolants earlier, and those will be additional cases where the NRC will, I hope, inform their licensing decisions by departing from deterministic regulations and devoting careful attention to risk.

Lessons Drawn from the Fukushima accident

I'd like to close with comments about the Fukushima accident in Japan and the steps that the Japanese government is taking to rebuild confidence in their industry because they are illustrative of the excellence of the U.S. NRC and INPO roles. I noted that the NRC learned a great deal from TMI, and the U.S. nuclear power industry and U.S. taxpayers have been beneficiaries. But the Japanese regulator prior to Fukushima, the Nuclear and Industrial Safety Agency (NISA) and the Japanese nuclear industry did not learn from Three Mile Island.

As one key point, NISA was influenced by industry, it was not independent, in that it reported to the Ministry of Education, Trade and Energy. This placed both regulation and promotion for nuclear power in the same organizations. This was a key lesson demonstrated by the United States in 1974 when those same two functions at the Atomic Energy Commission were moved into an independent NRC with no promotional responsibilities.

And as another key point, the NRC shared key new regulations with NISA after the 9/11 terrorist incident. These new regulations required, among other features, that all plants be able to withstand loss of large areas of a plant, which includes the possibility of a complete loss of power, known as a station blackout. Every U.S. plant is now so equipped, despite some significant costs. But when the NRC shared these new regulations with NISA, the response was

that such regulations were not needed in Japan because that set of events could not happen in their country. And then came the station blackout at Fukushima.

As the Japanese government has moved to improve their regulatory posture, they have set up a new Japan Nuclear Regulatory Agency, which is completely independent, just like the NRC. And as they work to further improve their safety record and develop public confidence, the Japanese nuclear industry has also set up their own version of INPO, called the Japan Nuclear Safety Institute or JANSI. Thus, the Japanese government and industry are now availing themselves of lessons learned in the U.S. after TMI. And these moves by Japan help, in my view, to demonstrate that in the U.S. we truly have the gold standard of regulation and safety, both from government and from industry.

The tsunami and the the Fukushima accident were a tragedy on many levels: in lives lost; lives disrupted; in Japan's energy portfolio, balance of payments, cleanup costs, and carbon emissions; and for the utility. But the fact remains that no fatalities were ascribed to radiation exposures. While that statement may sound positive, the evacuations required by the Japanese government led to many fatalities among the elderly population, with estimates between 1200 and 2000. Those fatalities caused by the evacuation are still a result of the accident.

Those evacuations were conducted from an abundance of caution, perhaps an overabundance, and from a very poor understanding of the effects of low doses of radiation. Unfortunately, if there were an event anywhere in the world., like a dirty bomb explosion, we would be just as helpless as was Japan in understanding what level of evacuations to recommend.

The U.S., Japan, and, in fact, the whole world, use estimates for the effects of low doses of radiation that are simply not based on any credible science. We all use estimates of radiation effects that are largely extrapolated to low doses from the large instantaneous radiation doses that were experienced in the nuclear explosions in Japan. This assumes that people respond in a precisely linear fashion to radiation exposures, which is quite an assumption. In the case of radiation, we all live in sea of low-dose radiation from natural radiation from rocks and cosmic rays, and it seems reasonable that humans have evolved to some degree of adaption to low-dose exposures!

When I worked with Senator Domenici, he legislated the creation of a research program in the Office of Science of DOE to understand the effects of low doses of radiation and tremendous progress was made. For example, the research showed that the linear extrapolation for low doses of radiation is not correct. But unfortunately, and over my strongest objections, the DOE in the last Administration, chose to stop the research before determining the best model to replace the linear extrapolation and the Office of Science even refused my offer to use funds from my Office for their travel costs so they could at least understand the low-dose radiation effects studies ongoing in Europe. Several bills have been introduced to restart that DOE program, and I hope that we will soon see re-creation of that research effort. Without that research, we and the entire world will be no better prepared than was Japan to deal with a low-dose radiation incident. +

Better understanding of low-dose radiation effects could significantly impact the NRC and the commercial nuclear industry. It could change the criteria for radiation exposures now applied by NRC, EPA, INPO, the medical industry, the environmental cleanup industry, etc. For example, if the current linear extrapolation is judged to be too conservative, this might help to address the public's fears concerning low-dose exposures. Better understanding should certainly lead to different criteria being applied in any future evacuations that may ever be required, with far greater certainty that the risks of potential radiation exposures are properly balanced against the risks of evacuating elderly citizens. It could change the current focus throughout the nuclear industry, and certainly at the NRC and INPO, for achieving doses that are "As Low As Reasonably Achievable" (known as the ALARA principle). The strict application of ALARA in the commercial nuclear industry increases operating costs, for example, some maintenance might be possible during reactor operations, instead of doing most of the maintenance only during outage periods. This could provide some efficiencies to the nuclear industry.

But the purpose of a low-dose radiation effects program will be to provide a solid basis for regulations, and it is not impossible that research will show that radiation exposures need to be still further reduced. Personally, I doubt that will be the outcome, but I absolutely do not want to prejudge the outcome of the research! The research needs to be conducted completely divorced from any pre-conceived notions of the outcome!

Conclusions

- The United States is at serious risk of losing its domestic nuclear energy program. With that loss, our grid will suffer from loss of fuel diversity, reduced resilience and reduced reliability; plus, the nation would lose the immense national security benefits we currently accrue. And, without a vibrant domestic industry, there is no possibility of deploying advanced reactors in the future.
- The weak position of our domestic nuclear industry is destroying our ability to compete on the international nuclear energy market. Without Congressional leadership to change this situation, we are ceding global leadership in nuclear power to Russia and China and enabling them to set the nonproliferation and safety standards for the world.
- I strongly recommend that Congress re-evaluate the plan to dispose of 34 tons of weapons-grade plutonium in a manner that does not support advanced reactor demonstrations, wastes immense quantities of taxpayer resources, and fails to fulfill an international commitment dating to 2000.
- Without a credible used fuel management policy, all new nuclear deployments will struggle. Congress should move towards a credible, bipartisan, funded, used fuel management policy. My recommendation is to try the consent-based approach towards siting both interim storage and a repository and explore how a reprocessing capability or other emerging technologies (like deep boreholes) might change the public debate on used fuel.
- The U.S. is positioned to demonstrate global leadership on innovative advanced nuclear designs. But continuous learning and a progressive shift to risk-informed regulations at

the NRC are essential to the domestic nuclear industry and to evolution towards deployment of advanced reactors.

- Congress should continue to encourage restart of the low-dose radiation effects program, which will benefit any of the countless uses of nuclear technologies, as well as enable credible responses to any global situations involving potential low-dose radiation exposures.