Attachment-Additional Questions for the Record

The Honorable Larry Bucshon, M.D.

1. How would the implementation of advanced nuclear reactors align with broader national energy strategies and efforts to provide reliable, affordable, and efficient energy to consumers?

Answer: Nuclear energy today produces nearly 20% of America's electricity and approximately half of our emissions-free electricity. To meet rapidly accelerating energy demands and carbon-reduction goals while ensuring our nation's energy independence, we need to deploy advanced reactors quickly, affordably, and efficiently. This urgency is why the U.S. and other nations have agreed on a goal of tripling nuclear energy production by 2050. The development and construction of advanced reactors would enhance our nation's energy security, national security, and environmental sustainability for decades.

Nuclear energy is the most-reliable and resilient source of firm, baseload, carbon-free energy. Data from 2017 shows that nuclear power plants operated at full capacity over 92% of the time, making them the most reliable energy source in America. This reliability is nearly double that of coal (54%) and natural gas (55%) plants and two to three times greater than wind (37%) and solar (27%) plants. Designed to run 24/7, nuclear power plants require less maintenance and can operate for extended periods before needing refueling, typically every 1.5 to 2 years.[1]

While nuclear power plants require a large upfront investment to construct, their operational expenses are relatively low. In many regions, nuclear energy competes favorably with fossil fuels for electricity generation as often the costs of waste disposal and decommissioning are typically factored into its operating expenses. Moreover, when considering the social, health, and environmental costs of fossil fuels, the competitiveness of nuclear power further improves.[2] Additionally, as we develop and deploy advanced reactors, they will become more affordable. Supply chains and expertise will expand. For example, the cost of Southern Company's Vogtle 4 unit was 30% less than Vogtle 3. In addition, advanced reactors provide reliable and affordable energy for upwards of 80 years providing stability and certainty to communities facing growing energy demands.

Advanced reactors also present a unique opportunity for former fossil-energy communities. According to a 2022 U.S. Department of Energy report,[3] coal-to-nuclear conversions offer a tremendous opportunity to preserve the economic viability of communities that built the nation's economy.

Another advantage of advanced reactors is that they require far less land than other forms of energy production. A typical 1,000-megawatt nuclear power plant in the U.S. needs about one

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1 https://www.energy.gov/sites/prod/files/2019/01/f58/Ultimate%20Fast%20Facts%20Guide-PRINT.pdf.

2 https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power#:~:text=Nuclear%20power%20plants%20are%20expensive,included%20in%20the%20operating%20costs.

3 https://fuelcycleoptions.inl.gov/SiteAssets/SitePages/Home/C2N2022Report.pdf.

square mile to operate, while wind farms require 360 times more land area and solar photovoltaic plants need 75 times more space to produce the same amount of electricity.[4]

In addition to providing reliable, firm, baseload, carbon-free electricity to the grid, advanced reactors are being designed for a variety of electric and non-electric applications. High-temperature reactors, like X-energy's Xe-100, can provide electricity and process heat for industrial applications, such as the planned facility at Dow Chemical in Texas. TerraPower's Natrium reactor will be deployed at a retired coal site, rejuvenating an existing energy community. The Natrium reactor will also feature an integrated energy-storage system to enhance flexible operation and integration with intermittent energy sources.

Microreactors are being developed to support remote operations and off-grid applications. Department of Defense programs will employ mobile microreactors at forward operating bases and stationery small modular reactors (SMRs) for other bases. Advanced reactors are also being considered to power enhanced oil and gas recovery and certain mining operations. Additionally, advanced reactors will be able to run on spent nuclear fuel (SNF), reducing the nation's nuclear-waste burden, improving resource utilization while ensuring energy independence. Finally, advanced reactors can help power hyperscale data centers in the U.S. as they look to build out such technologies as artificial intelligence and to power the growing digital economy. This was seen recently when Amazon Web Services purchased Talen Energy's nuclear-powered data center in Pennsylvania.

2. What role could advanced nuclear reactors play in reducing future amounts of spent nuclear fuel produced by both civilian and defense applications?

<u>Answer</u>: Advanced reactors have an important role to play in reducing legacy and future inventories of spent nuclear fuel (SNF). Many advanced reactors are designed for improved performance and fuel utilization. For example, recent studies estimate that two Advanced Reactor Demonstration Program (ARDP) projects, TerraPower's Natrium and X-energy's Xe-100, will reduce SNF mass by 70% or more relative to light-water reactors (LWRs) in operation today.[5] Other advanced reactors can be designed to operate on recycled nuclear fuel, thereby reducing the volume of high-level waste requiring disposal by about one-fifth. Recycling SNF in advanced reactors could also significantly reduce the longevity of the radiological hazard of SNF requiring disposal, depending on the chosen recycling scheme. However, while advanced reactors can improve uranium-resource usage and minimize nuclear-waste generation, especially when operated as part of a closed nuclear fuel cycle—i.e., one that recycles SNF—they will not eliminate the need for a geological repository.

3. Will there be different characteristics of the waste produced by these advanced reactors and how will that affect the designs of the repository for the spent fuel?

<u>Answer</u>: Waste generated by advanced reactors will differ, in most cases, from waste generated by LWRs in operation today. However, many of these new advanced-reactor

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4 https://fuelcycleoptions.inl.gov/SiteAssets/SitePages/Home/C2N2022Report.pdf.

5 https://fuelcycleoptions.inl.gov/SiteAssets/SitePages/Home/SMR_Waste_Attributes_Report_Final.pdf.

fuels are similar to legacy fuels that were included in the original repository license application, although generated in amounts smaller than LWR SNF. Advanced reactors of varying designs and fuel types will generate waste with different characteristics. Many advanced reactors will generate less waste, with a reduced radiologic hazard compared to LWR SNF, especially if SNF is recycled. The specific characteristics of advanced-reactor waste will vary by design, including different fuel geometries, levels of fuel utilization, and chemical forms. Some designs will have improved disposal performance in certain aspects, while other characteristics may be less favorable. For example, some advanced reactors will use sodium-bonded fuel that will require processing prior to disposal. As noted in my testimony, a key difference between existing- and advanced-reactor waste is that existing nuclear fuels are designed for reactor performance, not long-term geologic repository performance. If nuclear-fuel recycling is implemented, waste forms can be designed to improve repository performance and expand repository options.

The Honorable Diana DeGette

1. Given the Committee's interest this Congress in licensing advanced reactors, I want to make sure we're going in with our eyes open on any potential benefits or challenges associated with storing spent fuel from advanced reactors.

   For example, my understanding is that the fuel for the Experimental Breeder Reactor II was "sodium-bonded," and that sodium-bonded fuel would have to undergo some type of additional processing before being stored in a permanent repository. Could you give any additional details on potential treatments or other differences relative to "traditional" reactor fuels that we should be aware about for spent fuel from advanced reactors?

Answer: Waste generated by advanced reactors will differ, in most cases, from waste generated by LWRs in operation today. In general, these advanced fuels will offer enhancements compared to existing LWR SNF. Many advanced reactors will generate less waste, with a reduced radiologic hazard compared to existing LWR SNF, especially if SNF is recycled. For example, TerraPower's Natrium reactor, which will initially utilize sodium-bonded fuel, will generate 72% less SNF mass compared to LWR SNF.[6] However, as you note, such fuel will require treatment prior to disposal in a geologic repository. Conversely, TRISO fuel, such as used in X-energy's Xe-100 reactor, will have improved performance in all disposal schemes because the outer fuel coatings also serve as a self-contained waste form.

Specific to your question, sodium, which is considered a reactive metal, requires treatment to passivate, or make unreactive, the material to meet environmental requirements associated with the Environmental Protection Agency's (EPA's) implementation of the Resource Conservation and Recovery Act (RCRA). Processing of the Experimental Breeder Reactor II (EBR-II) SNF was determined to be required to address concerns with sodium in discharged fuel before disposal. Thanks to this work, processed EBR-II fuel is

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6 https://fuelcycleoptions.inl.gov/SiteAssets/SitePages/Home/SMR_Waste_Attributes_Report_Final.pdf.

now providing a necessary feedstock for high-assay, low-enriched uranium (HALEU) to meet advanced-reactor needs until commercial HALEU enrichment comes online. In addition, INL continues evaluating advanced technologies to treat sodium-bonded fuels planned for use in some advanced reactors, and advanced fuels that do not require sodium bonding are under development.

Even though some fuels, such as sodium-bonded fuel, will require processing prior to geologic disposal, this could ultimately serve as an overall benefit to SNF disposal. For example, if existing SNF or advanced-reactor SNF is repackaged or recycled, alternative disposal options, such as deep boreholes, may become feasible. Such an approach could also offer local socioeconomic benefits by collocating recycling facilities, and the associated industries and high-paying jobs, with storage and/or disposal sites.

In summary, advanced reactors fuels are now being developed, not only with reactor performance in mind, but also taking into consideration repository performance. If nuclear fuel recycling is implemented, waste forms can be designed to significantly improve repository performance and expand repository options. This is also true for treatment or processing of sodium-bonded fuels, even if nuclear fuel recycling is not implemented.