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Office of Nuclear Energy
U.S. Department of Energy
1000 Independence Ave. SW
Washington, DC 20585

**Response to 86 FR 71055: Request for Information (RFI) Regarding Planning for Establishment of a Program To Support the Availability of High-Assay Low-Enriched Uranium (HALEU) for Civilian Domestic Research, Development, Demonstration, and Commercial Use.**

The American Nuclear Society, representing over 10,000 nuclear technology professionals, is pleased to respond to the Department of Energy (DOE) request for information regarding high-assay low-enriched uranium (HALEU) for civilian use. We strongly support the creation of a HALEU availability program in alignment with Section 2001 of the Energy Act of 2020. The availability of HALEU is critical to the continued development of advanced nuclear technologies, and actions taken to establish a HALEU supply chain will support the DOE's efforts to deploy and commercialize clean energy technologies and infrastructure. Further, the DOE's substantial investments in the Advanced Reactor Demonstration Program (ARDP) are at risk of significant deployment delays without the expeditious development of HALEU infrastructure.

Integration of governmental, regulatory, and industrial efforts across all aspects of HALEU infrastructure development (enrichment, deconversion, and packaging/transportation) will be required to ensure the availability of HALEU and the continued advancement of clean energy technologies. We believe that technical solutions are accessible for the storage, transportation, and disposal issues raised in the DOE's request for information and that the development of a HALEU availability program should be pursued without delay. In cases where transportation, storage, and disposition solutions could benefit from refinement and/or external analysis, we believe that the Office of Nuclear Energy, and especially the Fuel Cycle Technologies (FCT) initiative, is well positioned to provide input. The major thrusts of the FCT initiative deal directly with many of the questions outlined in the request for information and with other questions that may be raised regarding complete fuel cycle impacts of HALEU. As an example, the Material Protection, Accountability, and Control Technologies program and Advanced Reactor Safeguards program both have expertise that would be highly valuable to commercial entities seeking to implement Category II protections for a specific facility or technology. The Used Fuel Storage and Disposition initiative is versed in direct disposition and would provide valuable input on how HALEU material could affect direct disposition concepts. We recommend that these types of existing programs, both within the Office of Nuclear Energy and elsewhere, be provided the necessary resources to support identification of the most technologically suitable solutions for the rapid deployment of HALEU fuel cycles within the United States.

We have responded to selected questions in Attachment 1 and welcome additional opportunities to support DOE efforts to create a HALEU availability program. If you have any questions, please contact John Starkey—jstarkey@ans.org.

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Sincerely,

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**Attachment 1**
**Response to Selected Questions**

**(4)(c) If the Department were to address the objectives of *Sec. 2001 of the Energy Act of 2020* related to the creation of a fuel bank to supply HALEU for civilian domestic research, development, demonstration, and commercial use, what siting and energy justice issues should the Department take into account as it considers the development of a program and how might the Department address those issues?**

Nuclear facilities, including research reactors, power generation reactors, fuel fabrication facilities, medical radioisotope production facilities, and other radioactive materials handling facilities, are operated safely and with limited environmental impact across the United States.[1] We believe that compliance with existing regulatory frameworks will ensure that any new facilities can be operated with minimal environmental, health, and safety (EH&S) implications to the surrounding land area and populations. We also believe the construction and operation of HALEU infrastructure is likely to result in economic benefit to the surrounding populace with the creation of skilled jobs for people of diverse educational backgrounds (ranging from high school graduates to credentialed scientists). Many operational jobs may require only vocational or on-the-job training, reducing the barrier of entry for disadvantaged communities. There will also be notable benefits to U.S. leadership in nuclear reactor technology deployment, with potential material, fuel, and reactor supply contracts overseas.

**(8) Advanced reactors under development (including awardees under the Advanced Reactor Demonstration Program) would utilize HALEU in various chemical and physical fuel forms, including oxides, metals, and potentially salts. Additionally, centrifuge enrichment requires uranium in hexafluoride form. What additional fuel cycle infrastructure, or additions or modifications to existing infrastructure, would enable the deployment of commercial HALEU production and assure the availability of different forms of HALEU in sufficient quantities for use in advanced reactors?**

We believe existing low-enriched uranium (LEU) fuel suppliers have a potential business case for adding HALEU fuel manufacturing to their portfolios. Enrichers in the United States have the capability to deploy existing enrichment technology to produce HALEU at their existing sites. Existing fuel fabrication facilities, several of which are operating below their rated capacities, could also be used to establish commercial HALEU fuel fabrication capabilities. Such actions would have minimal EH&S impacts for the surrounding areas or peoples beyond the current EH&S profile. These facilities could manufacture HALEU fuel at assays below 10 weight percent (w/o) uranium-235 ($^{235}$U) with limited modifications. However, enrichment assays above 10 w/o $^{235}$U would require investments for separate facilities that meet the requirements for Category II nuclear facilities. We recommend that approaches to incentivize or facilitate this investment be evaluated, especially as the utilization of existing commercial facilities is one of the quickest ways to establish commercial HALEU enrichment and fuel fabrication capabilities given the accelerated timelines needed for advanced reactor development and deployment.

[1] "Safety of Nuclear Power." ANS Position Statement #51. American Nuclear Society. https://cdn.ans.org/policy/statements/docs/ps51.pdf?_ga=2.228905114.765505169.1644440177-812862292.1643897727 (current as of Feb. 11, 2022).

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**(11) What specific technological, regulatory, and/or legal gaps or challenges currently exist for transporting HALEU in various chemical forms (e.g., oxide, hexafluoride, metal) throughout the HALEU fuel supply chain? How do these challenges change depending upon the enrichment level? What actions could be taken, when, and by whom, to address the identified gaps or challenges?**

A robust, mature regulatory structure provides confidence that the safe transport of radioactive materials, including HALEU, will continue without adverse impacts to the public or environment. The transportation of LEU,[2] used nuclear fuel (UNF), high-level wastes, and other radioactive materials is conducted routinely with a graded risk-based approach for determining packaging and routes.[3] In fact, the international shipment of HALEU occurs regularly in the context of research reactor fuel resupply. Thus, the continued inclusion of HALEU shipments in a transportation portfolio is acceptable under the current regulatory structure.

The most common transportation package for LEU in the form of $UF_6$ is the high-capacity 30B cylinder. The role of 30B cylinders in HALEU transport is under analysis, and it is unlikely that 30B cylinders will be suitable for the entire HALEU enrichment range.[4] The U.S. Nuclear Regulatory Commission (NRC) staff has recommended that the NRC conduct a rulemaking regarding the transport of light water reactor fuel with enrichments above 5 w/o $^{235}U$.[5] Work has also been initiated within the DOE Office of Nuclear Energy (via the Gateway for Accelerated Innovation in Nuclear [GAIN] program) to evaluate the applicability and constraints for shipment of HALEU fuel in various forms. At the time of this writing, a license application for a modified cylinder suitable for HALEU-$UF_6$ has already been submitted by one stakeholder, and we believe additional designs may come forward. Industry is well equipped to design safe $UF_6$ transportation packages for certification by the NRC and other competent authorities.

Depending on the specific details of siting, desired fuel form (metal, oxide, fluoride, or other), and fuel fabrication processes, it is likely there will be cause to transport HALEU in alternative chemical forms. Many advanced reactor developers have indicated that they desire to receive HALEU in metallic or oxide forms.[6] Packaging for uranium metal and uranium oxide forms does exist currently, but these packages typically have low capacity. To support efficient transport of fuel for advanced reactors, higher-capacity packaging will be needed. We encourage expedient definition of this need, given the lead times required for designing, licensing, and fabricating transportation packages. Therefore, determination of the required qualifications and specifications of the feed materials for fabrication of advanced reactor fuel must completed at an early stage of the planning process.

[2] LEU is transported in the form of uranium hexafluoride ($UF_6$), uranium oxide ($UO_2$) powder and pellets, and as fabricated fuel assemblies.
[3] "Transportation of Radioactive Materials." Position Statement #18. American Nuclear Society. https://cdn.ans.org/policy/statements/docs/ps18.pdf?_ga=2.168997799.765505169.1644440177-812862292.1643897727 (current as of Feb. 11, 2022).
[4] E. M. Saylor et al. "Analysis of the 30B $UF_6$ Container for Use with Increased Enrichment." ORNL/TM-2021/2043. Oak Ridge National Laboratory. https://info.ornl.gov/sites/publications/Files/Pub158475.pdf (current as of Feb. 11, 2022).
[5] "Policy Issue, Subject: Rulemaking Plan on Use of Increased Enrichment of Conventional and Accident Tolerant Fuel Designs for Light Water Reactors." SECY-21-0109. U.S. Nuclear Regulatory Commission. December 20, 2021. https://www.nrc.gov/docs/ML2123/ML21232A237.pdf (current as of Feb. 11, 2022).
[6] "Establishing a High Assay Low Enriched Uranium Infrastructure for Advanced Reactors." Nuclear Energy Agency. January 2022. https://nei.org/resources/reports-briefs/establishing-a-haleu-infrastructure-for-advanced-r (current as of Feb. 11, 2022).

The design, licensing, and fabrication of new transportation packages for various forms of HALEU fuel may become a critical-path activity as package designers are unlikely to accept the risk of designing, licensing, and fabricating transportation packaging while demand for these packages remains uncertain. It is clear that government has a role in supporting the design, licensing, and fabrication of new HALEU packaging. Several actions are likely to prove beneficial. First, the DOE can work with reactor vendors and potential packaging designers to better define the demand for packaging, taking into account the uranium transport form, the fuel fabrication process, the expected fuel loading timeline, and the amount of fuel required. This will allow the packaging designers to solidify a business case for packaging development. Second, the DOE can support the design and expedient licensing review of HALEU-specific packaging from multiple vendors through any reasonable means available. Third, the DOE can help to ensure that existing packaging, including any necessary modifications to existing packaging certification, be made available in the interim period to support advanced reactor fuel fabrication timelines while new packaging is in the process of licensing and fabrication.

**(13) Co-location of facilities for the front end of the fuel cycle (such as enrichment, and conversion/deconversion, and fabrication) may be a practicable solution to address some HALEU transportation issues. Is co-location considered otherwise beneficial? Are there other solutions that should be considered?**

As stated in our response to question 11, the transportation of radiological materials, including HALEU, can be conducted safely under existing U.S. regulations. However, there are concerns regarding the availability of sufficient transportation packaging for HALEU fuel in various forms. Reduction of transportation issues may not of itself prompt the co-location of fuel cycle operations. Several other facets of co-location must be considered. First, the co-location of an enrichment facility and deconversion facility would enable the shipment and storage of uranium intermediate products (e.g., oxides or uranium metal). Second, co-location of fuel cycle facilities provides an opportunity to reduce the cost of front-end operations by enabling close process linkages. Third, as in many other aspects of HALEU usage, the issue of Category II nuclear facilities comes forward. There may be benefit in operating multiple Category II facilities at a co-located site with shared security.

Most importantly, any co-location and operation of facilities must consider the reactor vendors and their desired fuel form. Given the range of fuel types currently being proposed, the creation of a one-size-fits-all solution with a single uranium form may not be suitable to address fuel supply for potential fuel or reactor vendors. For example, deconversion of HALEU-$UF_6$ to uranium oxide may require some fuel fabricators to add additional conversion steps within their manufacturing processes. We recommend that careful consideration be given to balancing the many factors that will affect not only co-location, but also the chemical form of any potential HALEU supply chain. It may be found that multiple HALEU forms and enrichments are needed to enable the development of supply chains diverse enough to support emerging reactor technology. The DOE is well positioned to provide an objective analysis of potential HALEU products, their production processes, and the benefits or disadvantages of $UF_6$ transportation and handling by enrichment, deconversion, and fabrication facilities.

Although the case for co-location of HALEU enrichment and deconversion facilities is easily understood, the case for co-locating fuel fabrication facilities with other front-end operations is less clear. Given the potential for repurposing underused capacity at existing nuclear fuel fabrication facilities, the range of fuel concepts proposed, and the large number of potential

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HALEU reactor vendors and fuel vendors, it is likely that fuel fabrication facilities will need to be independent of other front-end operations and operated either by reactor vendors themselves or commercial fuel suppliers.

**(15) What are the technical barriers and/or regulatory requirements (e.g., safety, security, material control and accountability) to licensing front-end fuel cycle facilities (e.g., enrichment, deconversion, and/or fuel fabrication facilities) for the production and availability of HALEU?**

- **For existing facilities to upgrade to a HALEU capability?**
- **For new facilities?**

There is an established regulatory structure for Category II fuel cycle facilities, and the Centrus enrichment facility in Ohio was licensed to produce up to 20 w/o $^{235}$U in 2021. License application submittals for fuel fabricators are expected in the near future. Some uncertainties may be identified through these additional applications, but these uncertainties are expected to be limited in nature. Pending guidance from the NRC regarding material control and accountability for Category II facilities is expected to add clarity to licensing. Additional physical protection requirements will be in place, and the nuclear industry may explore physical protection design alternatives to reduce footprint and cost burden. Both existing facilities and new facilities will need support in this area. The Advanced Reactor Safeguards (ARS) and Material Protection, Accounting, and Control Technologies (MPACT) program areas in the DOE Office of Nuclear Energy are beginning to provide support to the nuclear industry with these issues—it is important to ensure adequate resources are available for this support in order to provide impactful results for industry.

Future facilities should take advantage of modern approaches to safety, safeguards, and security by design to optimize control and accountability systems. Regulatory requirements should be considered early in the design process in order to avoid costly retrofits in the future.

**(16) What, if any, additional criticality and/or benchmark data is needed to meet U.S. Nuclear Regulatory Commission (NRC) safety and regulatory requirements that must be met in order to establish a supply chain capable of making HALEU available for the development and deployment of advanced reactors? Please consider and address both front-end fuel cycle facilities and transportation packages (including for metal, gas, and pertinent chemical forms).**

State-of-the-art criticality analysis tools are very capable today, based on advances in the understanding of fundamental nuclear physics and improvements to computational methods and platforms. These tools should be sufficient to ensure adequate criticality safety for HALEU transportation packages, facilities, and processes. With that being said, additional data with prototypical HALEU enrichments, materials, and geometries would allow for margin improvements in anticipated HALEU fuel fabrication and transportation applications. We recommend that the national laboratories, with input from industry and regulators, perform a study on the potential costs and benefits of obtaining additional criticality and/or benchmark data. Such a study should be performed in a timely manner, but it should not be required prior to proceeding with initial designs and regulatory approvals associated with HALEU. Additional data, if obtained, would enable greater efficiencies in the longer term.

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**(17) What, if any, additional challenges or considerations may be associated with a HALEU lifecycle (including disposition), beyond those of a traditional light water reactor fuel cycle, and how can they be can be identified early and addressed?**

Numerous post-irradiation technical issues should be considered in the context of HALEU fuel. These include the following:

- Radiation shielding and decay heat dissipation requirements. Higher-burnup fuel may have additional requirements, and these will affect storage and transport of HALEU-based UNF. A number of options exist to address these concerns (e.g., storage and transport cask redesign or longer storage times prior to transportation), but a technology-specific evaluation of approaches is merited.
- Long-term criticality assessments associated with interim storage, transport, and disposal of HALEU UNF, if fuel recycle is not performed.
- The need for LEU or HALEU fuel recycle. Discharged HALEU fuel may have economic value greater than that of LEU fuel. LEU fuel may also be considered as feedstock for some advanced reactor designs.
- An analysis of how direct disposition pathways could be altered for HALEU versus LEU fuels.

The Office of Nuclear Energy, and especially the Fuel Cycle Technologies (FCT) initiative, is well positioned to address many of these storage, transportation, and disposition questions. We recommend the continued funding of the FCT initiative at levels such that issues can be evaluated in a time frame aligned with the expected deployment of HALEU-utilizing advanced nuclear technology.