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

February 14, 2022

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Table of Contents

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1. Introduction

On December 14, 2021, the U.S. Department of Energy (DOE or the Department) issued an RFI to invite input on the planning for establishment of a DOE HALEU Availability Program and to gather information to consider in preparing the required report to Congress describing actions proposed to be carried out by DOE under the program. The Energy Act of 2020 authorized the Department to establish and carry out, through the Office of Nuclear Energy, a program to support the availability of high-assay low-enriched uranium (HALEU) for civilian domestic research, development, demonstration, and commercial use. This document provides the response from Orano USA (Orano), a member of the global Orano Group with six decades of experience operating its conversion and enrichment facilities in France and delivering to international customers using its transportation packaging and services.

The U.S. is the largest commercial reactor fleet in the world. The commercial ecosystem for light water reactors and related services is well defined, with requirements known and capacity matched competitively with demand. The U.S. fleet is served by production facilities outside the United States across all segments of front end activities. This is a mature, well-organized global market and commercial ecosystem prepared to serve the needs of existing markets.

Nuclear energy is a technology with unmatched promise for delivering the de-carbonization required of our urgent global ecological challenges. It will require government and industry partnerships to accelerate development of critical supply chain capabilities for advanced nuclear systems. And it will require a workforce with an uncompromising safety culture and a commitment to materials accountability and non-proliferation. Orano is an experienced commercial actor committed to delivering this nuclear future.

An assessment of the infrastructure requirements to support advanced nuclear systems shows evident but bridgeable gaps. The focus of our response to this RFI is to define the steps and conditions necessary to ensure that a U.S.-based platform for commercial HALEU production is available to support advanced reactors. Enrichment capacity is one foundational element of the required infrastructure, but it would be a mistake to view any element of the advanced nuclear ecosystem in isolation. Perspective is offered on considerations for the design of a cost-competitive system driven by commercial solutions.

The role of the DOE in accelerating HALEU availability is essential, given the lack of initial offtake demand from the commercial market. As instructed by the Congress, the DOE must organize the collective power of the U.S. government and industry to deploy commercial capabilities as quickly and cost-effectively as an equitable process will allow. This will require a cooperative, market-oriented approach that assigns technology and financial risk appropriately. Firm quantity commitments backed by a HALEU Bank or similar mechanism(s) will be important for organizing and accelerating commercial investment in new HALEU production capacity.

2. Specific Questions on Which Information is Requested

Input was requested on information the Department should consider as it plans a program to support HALEU availability for civilian domestic research, development, demonstration, and commercial use.

To facilitate public input, this RFI included a set of specific questions on which the Department would appreciate input. These questions and the associated Orano responses are listed below:

Establishment of a HALEU Consortium & Market Development

(1) Sec. 2001 of the Energy Act of 2020 directs the establishment and periodic updating of a HALEU Consortium to partner with DOE to support the availability of HALEU for civilian domestic demonstration and commercial use. Among other things, the Act envisions that the HALEU Consortium could: provide information to DOE for purposes of biennial surveys on the quantity of HALEU needed for commercial use for each of the subsequent five years; purchase HALEU made available by the Secretary for commercial use by members of the consortium; and carry out demonstration projects using HALEU provided by the Secretary under the program.

What types of organizations or other entities should be included in the HALEU Consortium? If your organization or entity might be interested in becoming a member of a HALEU Consortium, please describe the contribution your organization or entity could provide to the consortium. The description should include examples of the type of activity or activities for which your organization or entity is interested in partnering with the Department. Please also provide a point of contact for your organization or entity, including name, affiliation, email, and phone number.

The HALEU Consortium convened by the DOE ("Consortium") should be objective-oriented and organized to surface information supporting the design of a vibrant and functioning market for HALEU production capacity and logistical ecosystem.

The Consortium should be designed to provide clarity in the formation of this market, which will assure a viable and competitive supply of HALEU across multiple chemical forms to fuel advanced reactors. The organization of this new market requires the direct support and commitment of the Department of Energy to establish market certainty and attract commercial investments that accelerate supply chain readiness for delivery of advanced nuclear systems across the world.

Ultimately, the Department of Energy's strategies for enabling commercial HALEU availability are the responsibility of the Secretary, subject to all of the appropriate process vetting required by Congress related to authorized scope and programmatic funding.

The Consortium should play a role in aggregating demand and leveraging that demand to guarantee supply availability. It should be designed to solicit and maintain a high-fidelity view of market requirements and specifications in order to inform the design of DOE's HALEU-based infrastructure requirements.

The Consortium must be commercially-oriented to ensure the cost-competitiveness of production conditions and segregated from the U.S. defense mission. The potential scope of Consortium participants should include representation from both the demand and supply perspectives (reactor vendors, utilities, front-end suppliers, fuel vendors, logistics providers, back-end suppliers, and industry organizations).

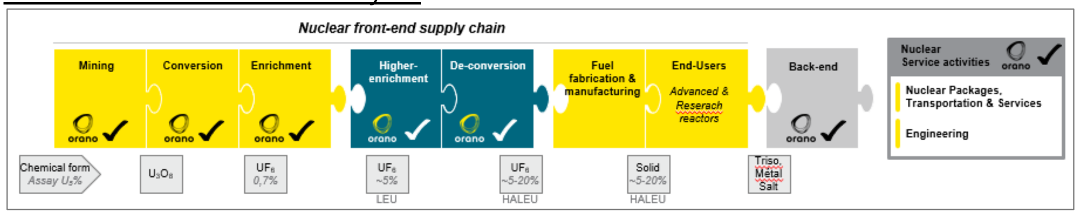
On the demand side, the Consortium should surface information on chemical forms, volumes, lead times/scale, competitive cost constraints, licensing and regulatory impacts, and materials management requirements. It should be careful to include perspectives on non-traditional applications and related requirements in addition to perspectives of advanced reactor developers, fuel manufacturers, and the research reactor user base. Additionally, the DOE should consider participants from outside of the U.S. to assess whether associated demand could be organized to improve the initial economics for U.S.-based HALEU production through increased depth of demand. Appropriately designed, this could mitigate risk for both DOE and HALEU producers during initial market formation.

On the supply side, the Consortium should surface information on technologies, lead times, development costs and economics, licensing and regulatory impacts, and packaging requirements. It should include the industrial players of the nuclear fuel cycle, along with providers of enabling services, materials management, e.g., designers of packages, transportation, and storage.

Additional beneficial functions of the Consortium include serving as a forum for the development of regulatory recommendations for the NRC and IAEA, as needed.

Orano USA (Orano) enjoys a unique positioning across the fuel cycle, as captured in the figure below. Orano's extensive expertise and industrial readiness is positioned to support the Department of Energy's development and deployment of advanced reactors and the delivery of a competitive and viable HALEU ecosystem.

<u>Orano in the Nuclear Fuel Cycle</u>



- As co-owner of ETC (Enrichment Technology Company) with Urenco, Orano benefits from ETC's unmatched expertise and performance for the development of an industrial high assay enrichment capacity;
- As a competitive commercial enricher with an extensive track record, Orano has industrial readiness for enrichment projects;
- As a significant market presence with decades of fulfilled contracts for uranium, conversion, and enrichment services in the United States, Orano is fully committed to serving the needs of its American customers and supporting the development of the American nuclear energy industry;
- As the sole European converter and nuclear chemistry operator, Orano has a recognized expertise in uranium chemistry and a proven technology for uranium transformation, including deconversion from UF6 to oxide, UF4, and metal;
- As demonstrated by the success of Orano's George Besse II enrichment and Comurhex II conversion industrial modernization projects, Orano's combined expertise in the fields of engineering and nuclear operations minimizes the risks associated with the design, construction, startup and operation of a new nuclear industrial asset;
- Orano's industrial capabilities have been developed internally through our own engineering groups, with detailed knowledge management systems that allow delivery of expertise and industrial process knowledge to reduce overall project risk;
- As one of the only commercial actors integrated throughout the entire fuel cycle, Orano has the technical expertise to efficiently plan for and support all aspects of a HALEU supply chain, including storage, transportation and logistics.

Orano is willing to support the development of this new market and stands ready to participate as a member of this Consortium. Orano's participation can be facilitated through Dr. Dorothy Davidson, President of Orano Federal Services (dorothy.davidson@orano.group) at our Bethesda, Maryland, headquarters.

(2) Please identify any issues, including energy justice concerns, that may affect the implementation of the HALEU Availability Program under Sec. 2001 of the Energy Act of 2020, in an equitable manner that would further the development and deployment of advanced reactors and the establishment of a domestic commercial source of HALEU.

While not directly applicable to the Consortium's mission, principles of Environmental Justice should be integrated across planning efforts, and will ultimately benefit the DOE, its commercial partners, and the facility host communities.

Orano's corporate mission is to develop and deliver know-how in the transformation and control of nuclear materials for the climate, and for a healthy and resource-efficient world, for now and tomorrow. To achieve this mission, Orano's operations are organized around maximizing the value of nuclear energy and delivering the full value from nuclear materials.

As a commercial nuclear services provider, Orano owns and operates industrial facilities across the world. This perspective as an operator informs how we engage with communities and governments to ensure our operations deliver sustainable, positive impacts in our communities and throughout the world. This engagement is defined in our corporate values and social responsibility charters, and supported by transparent environmental monitoring and metrics. Orano facilities are strongly integrated with and supported by the communities in which we operate.

The Consortium is not a siting authority and should not be viewed or operated as one. Siting considerations are addressed through other defined processes that ensure appropriate evaluation of impacts and provides access for intervention or objections. It would limit the effectiveness of the Consortium if participation or mission were to extend beyond the purpose of organizing commercial participants to directly participate in initial market formation.

(3) What are the most significant barriers to the establishment of a reliable market-driven, commercial supply of HALEU for advanced reactor research, demonstration, and commercial deployment? Please describe these barriers in detail, identify potential actions to address these barriers, and include the timeframes in which the issues should be addressed.

Traditionally, the nuclear industry has operated with commercial enrichments of 5% 235U (Low Enriched Uranium "LEU"), with the associated industrial supply chain, legal, and regulatory frameworks designed accordingly.

Supplying the range of emergent advanced reactor concepts with a sustainable, cost-competitive fuel supply will require new dedicated enrichment capacity along with associated chemistry services (“deconversion”) that ensure this capacity can ultimately be accessed for utilization through a variety of chemical forms that will be demanded by the market.

Bridging to a HALEU ecosystem from the existing commercial nuclear value chain will require large commercial investments in new industrial capacity, and will present certain challenges related to increased fuel enrichments that will directly impact many of the established fuel cycle steps and sub-steps, requiring evolutions to both infrastructure and regulation.

There are four key barriers to the establishment of a reliable, market-driven commercial supply of HALEU: technological, industrial, financial, and logistical.

For commercial HALEU production capacity to fuel new advanced reactor concepts, a platform of technologies must be mastered on an industrial scale:

(i) Isotopic separation in order to enrich the uranium to assays up to 20% U235;
(ii) Chemical transformation of the fissile material in order to de-convert the enriched UF6 into the appropriate chemical form required (oxide, UF4, metal); and
(iii) Manufacture of these new fuels which will then be introduced into the advanced reactors (salts, TRISO, metal).

Access to credible and proven technology for both enrichment and deconversion services is a threshold barrier for development of this HALEU production capacity. In delivering commercial capacity, there is no room for technology risk that introduces schedule or operational challenges. To compete in the market, advanced nuclear reactors require proven, state-of-the-art technologies for highly competitive and reliable fuel production. This must be delivered through an industrial platform designed and built to safely account for the criticality of such assay levels.

Overcoming industrial barriers will require access to industrial know-how for the development of a scalable and adaptable design. This expertise will be critical to establishing cost-competitive operating parameters that will define the underlying economics for commercial HALEU production capacity. Firm design specifications, production requirements, and delivery timelines are necessary for defining licensing and operational requirements, and will strongly influence capital investment schedules.

The uncertainty of design and industrial specifications is reflective of larger commercial uncertainties that could prove a significant barrier in the financing of new HALEU production capacity. Principal among these commercial uncertainties is the lack of firm, sufficient offtake or utilization demand. This creates a “chicken-and-egg” situation for the industry where (i) investors are reluctant to put money into advanced reactor construction without an established fuel supply, and (ii) fuel suppliers are equally unwilling to license and construct the necessary enrichment and deconversion capabilities until they have received commercial commitments that guarantee a certain volume of demand. As such, strong policy support will be determinative in the attraction of initial commercial investment.

Finally, in transitioning to higher enriched materials, the industry faces barriers (mainly technical and regulatory) in accessibility to suitable transportation packages able to ensure the sub-criticality of the material during transportation. Orano is developing packages to support such transport, as discussed in response to Questions 11 and 12 of this RFI.

DOE can reduce these barriers to commercial HALEU availability through resources that support a fast-track design and licensing process for the future facilities. This will accelerate industrial readiness and, when coupled with defined offtake agreements, will support investment in an industrial platform. In the design of these public-private partnerships, technology risk should be borne primarily by industry in alignment with existing commercial expertise in enrichment, deconversion, packaging, and logistics. On the other hand, economic risk must initially be borne by the DOE to sufficiently reduce the investment risks posed by an uncertain demand environment.

DOE programmatic support for commercial HALEU production capacity should seek to organize and aggregate firm demand, with associated volumes, isotopy, delivery dates, and chemical and physical forms as soon as possible. As noted previously, commercial technology design and licensing parameters will be driven by these inputs, but require time and investment for appropriate safety and environmental reviews.

(4) 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 is the quantity (in metric tons/assay) of HALEU necessary for domestic commercial use for each of the next five years (2022-2026)?

If a "stockpile" of HALEU were established to build confidence in the supply of HALEU supporting early orders for the deployment of advanced reactors in the commercial market, how large (in metric tons/assay) a stockpile would be needed?

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?

The lack of firm demand signals is identified as a critical barrier preventing commercial and significant investment in HALEU production capacity, as discussed in response to Question 3. Sufficiently overcoming this barrier will require the strategic and financial commitment of the DOE to guarantee initial offtakes and assure commercial availability of HALEU material for advanced nuclear applications. This can be accomplished through a range of potential purchase commitments or guaranteed offtakes that would enable commercial investment in HALEU production capacity and assure material availability to support the aggressive deployment of advanced reactors in the U.S. and internationally.

Because of an inherent continuous production process, production output must be maintained to avoid prohibitive operating costs. As this is a developing market, the industrial platform must account for continuous operations through design of modular production capacity (in terms of volume and chemical forms), with the design and capability to quickly and flexibly scale operations.

The initial quantities required for a cost-competitive commercial HALEU production capacity exceed the demand of the existing market commitments, including material requirements for Advanced Reactor Demonstration Project (ARDP) installation. The DOE should be prepared to guarantee offtakes and utilization in excess of this existing market demand as a condition of commercial investment.

To this end, the establishment of a HALEU Bank or related concepts ("HALEU Bank") could serve multiple beneficial purposes. First, it would provide for a mechanism for DOE to establish and manage guaranteed offtake commitments. This would allow the design of DOE's programmatic support for HALEU availability to be delivered through the same contractual mechanisms (e.g. offtake agreements) that are familiar to commercial participants and routinely serve as the basis for capital investment decisions. Second, a HALEU Bank would allow for introduction of greater price discipline and competition – important components of a functioning commercial market. Finally, a HALEU Bank would provide a means through which physical inventories can be optimized pending ultimate provision to customers.

The optimization of physical inventories is an important area for consideration in design of a HALEU Bank. To the extent practicable, a HALEU Bank should utilize innovative financial tools that maximize financial assurances while minimizing associated physical inventories under management. For simplicity and accessibility, a HALEU Bank should organize purchases of UF6-based inventories or financial instruments, with assured access to capacity for deconversion into specific chemical forms on-demand.

Programmatic design for commercial HALEU availability must be careful not to encumber access for utilization of the HALEU that is ultimately produced. It will be important that a HALEU Bank avoid introducing constraints that limit the range of physical forms available in the market. As U308, UO2, UF4, and metallic forms will all be required, physical inventories should retain flexibility for delivery of HALEU products across all chemical forms.

A HALEU Bank is unlikely to be a sufficient stand-in for robust commercial demand pull over the long-term. It is in the collective interest of commercial participants to transition as expeditiously as possible to HALEU production organized around direct capacity subscriptions and deliveries under commercial contracts. This interest is consistent with DOE's statutory mandate for temporary programmatic support, which should be provided by processes informed by principals of Environmental Justice as discussed previously in Question 2

(5) Please identify any additional specific actions that would provide confidence in the short-term supply of HALEU and thereby to ensure the development of a commercial market for advanced reactor orders.

What actions might be most useful for the U.S. Government to carry out?

What actions might be most appropriate for the private sector to carry out?

For advanced reactors to be deployed at the scale necessary to meet decarbonization goals, developers and their customers must have clarity of confidence that a HALEU production capacity, including deconversion, will be available from geopolitically stable sources, at competitive prices, for the operating life of their investments.

DOE should act in four key areas to enable commercial HALEU production. First, and most importantly, DOE must focus on standing up a viable, competitive, commercial market through targeted, strong, durable demand signals. Existing HALEU demand, even with ARDP installations, is insufficient to attract commercial investment in HALEU production capacity. DOE will need to organize, aggregate, and assure future demand informed by the Consortium discussed in Question 1 and assisted by mechanisms for offtake guarantees such as a HALEU Bank as discussed in Questions 3 and 4.

Second, the DOE should support the acceleration of ARDP fuel qualification and encourage finalization of specifications for chemical HALEU forms in order to accelerate design maturity for deconversion capacity. As specifications firm and designs mature, DOE should work through its interagency leadership position to ensure dedicated NRC resources for related licensing actions are made available, as well as to facilitate coordination on any international agreements.

Third, the DOE should work to assure availability of a suitable licensed transport fleet, compliant with the existing industrial facilities and international regulations, to service the emerging HALEU ecosystem. This can be accomplished through establishment of Cost-Shares to complete licensing for transport packages and by investing in the manufacture of packages through capacity payments or utilization guarantees as discussed in Question 11.

Finally, DOE, with the support of Congress, must continue to drive the development of technologies and the market for advanced nuclear reactors. One aspect of this is the successful licensing and delivery of demonstration projects in the ARDP program. Another is the design and availability of additional policy incentives for domestic advanced reactor deployment, including investment and/or production tax credits and loan guarantees. Ultimately, HALEU availability is a means to enabling an advanced nuclear future, with significant stakes for U.S. competitiveness, job creation, and ability to meet deep de-carbonization objectives.

The private sector can act in three key ways to enable commercial HALEU production. First, industry should develop operational plans, interfaces, and final designs for HALEU higher-enrichment and deconversion capacity based on standard existing specifications. This will allow the confidence needed to execute commercial licensing strategies, which can be accelerated through contributing DOE Cost-Share resources and offtake agreements. The licensed framework should reflect staged, modular deployment of capabilities, and the ability to flexibly manage the range of HALEU chemical forms needed.

Second, the private sector must demonstrate a willingness to accept appropriate performance and technology risk, and secure the financial and human resources needed to successfully deploy commercial HALEU production capacity.

Finally, the private sector must actively engage with communities and stakeholders around facility sites to educate on project impacts and establish active participatory conversations that surface and incorporate local and regional needs and perspectives, and environmental justice objectives.

(6) What level of market demand for HALEU over what timeframe is needed to stimulate investment in the infrastructure required to support a HALEU supply chain?

There is a familiar, proven process in the commercial market for evaluating capacity requirements and related capital investments. This process is based largely on commercial contracts for production offtakes, which serve to finance and allocate capacity. These offtakes are driven by the operational requirements of purchasers, as influenced by the market conditions and informed by price and competition. This level of demand signal does not yet exist in the market for HALEU production, and the DOE will need to play a central role in guaranteeing offtakes in order to leverage commercial capital investment, as described previously.

The capital, licensing, and operating requirements associated with the establishment of industrial HALEU production capabilities are significantly larger than the comparative costs for future expansion of those capabilities. Given the spread between current and anticipated demand requirements, HALEU production capacity should employ modular design concepts and secure a broad licensing framework to accommodate future growth in capacity and scope of activity. This is particularly true for deconversion, which will require a flexible capability to support the range of potential chemical forms demanded by innovators in an emerging market.

A successful DOE approach will ensure HALEU production is available, accessible in the required physical forms, and commercially cost-competitive. Because key cost and scope inputs remain undefined, it is not possible to define the specific levels of demand needed in order to stimulate uncertain levels of production. However, given Orano’s depth of industrial experience, we can discuss with the DOE notional demand and investment curves that are better informed through iterative conversations that would involve commercially sensitive data.

(7) On what basis should HALEU be priced or valued? Please consider the options for the pricing of HALEU based on enrichment, weight, and/or separative work units and provide the pros and cons for each option or combination of options. Please discuss how pricing options would provide DOE with reasonable compensation and commercial entities with sufficient incentive to deploy domestic capacity to supply HALEU. What is your long-term estimated "price point" for the range of assays/enrichment (2030 and beyond)? Please consider and note the form of HALEU (e.g., metal, oxide, UF6, etc.) in your response.

The market served by HALEU production and related services should be designed to develop as a free market where pricing is set by buyers and sellers. This is likely to look different in some ways than the market served by LEU production and related services. Requirements will be less commodified, with different user/supplier dynamics, participating in different markets.

The cost model for HALEU is likely to be different from that which applies to LEU commodities and services. At this stage, "HALEU" is not a fungible commodity, but a product to be delivered across a variety of chemical forms, and managing higher enriched materials require specific safety features. Installed capacity will require the industrial flexibility and modularity to respond to this range of potential commercial requirements. With higher relative fuel costs and a broader range of potential applications in the advanced reactor market, we are likely to see a continued need for flexible production outputs.

Because market preferences are still emerging, both modularity (of scale) and flexibility (of chemical forms) will be essential design characteristics for a successful commercial HALEU production platform. This will maximize access to the benefits of HALEU production and reduce risk and long-term costs for market participants.

The price of HALEU products must cover capital expenditure, operational costs including end-of-life, and a fair return on capital employed. Some of these cost elements are well-established. For example, to minimize the amount of investment, the first HALEU facility would use LEU as a feed for the enrichment unit. For this feed, the uranium material, conversion services, and SWU are well established and will constitute a certain portion of the final HALEU price. As an indication, UxC anticipates LEU price (U_3O_8, Conversion, SWU) to rise by more than 70% between 2022 and 2035. Some additional economic efficiency could potentially be gained through the utilization of LEU+ as feed, if it is available and competitive.

All other cost parameters have yet to be clearly defined through specification: higher enrichment capacity; deconversion into solid forms; packaging for transportation, reserve storage. Given Orano's depth of industrial experience, we are prepared to provide DOE with additional details around impacting cost inputs that are better arrived at through iterative conversations that would involve commercially sensitive data.

HALEU Supply Chain Development

(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?

Advanced reactor designs leverage the higher enrichments of HALEU to provide fuel and safety innovations designed to improve efficiency and economic operations.

The utilization of innovative fuels has emerged as a primary differentiator in the operation of advanced nuclear systems. Accessible commercial HALEU production capacity would provide the industrial basis for developers to further innovate, add value, and compete around the deployment of these and other new fuel technologies.

We envision an extended period of time whereby developers and end-users will compete around the delivery HALEU-fueled systems across a range of markets and applications. Ultimately, developers and end-users will benefit from the ability to match physical forms and configurations of HALEU to a range of markets and applications.

Delivery of this production platform is foundational and would extend capabilities of the existing supply chain to include HALEU enrichment (from LEU+ to 19.75%); deconversion in metal, UF_4 or oxide; fuel fabrication facilities; and commercially-sized transport packages for HALEU metal, salt, oxide, and UF_6.

(9) How do you envision a HALEU supply chain as being responsive to the President's Justice40 Initiative—a plan to deliver 40 percent of the overall benefits of climate investments to disadvantaged communities and inform equitable research, development, and deployment within DOE? Please provide specific actions and the type of benefits (e.g., employment, educational opportunities, etc.) that could be most useful to the targeted communities in response to the Justice40 Initiative.

Please refer to prior perspective provided in response to Question 2.

(10) What are some approaches or contracting vehicles that could be used by the Department to help enable the necessary commercial deployment of a domestic HALEU supply chain, including but not limited to mining, conversion, enrichment, deconversion, transportation, and fuel fabrication? For each, please discuss potential federal versus private sector actions; in addition, discuss leveraging robust partnerships for co-development of sub-elements of the supply chain. Possible approaches that might be considered include:

- ***Production contracts (of what volume and length);***
- ***Take-or-pay contracts (U.S. Government agrees to take specified volume of goods and/or services for a specified time period);***
- ***Partnerships and/or cost-sharing of infrastructure development, including with allies and partners; and***
- ***Payment-for-production milestones.***

DOE must structure programmatic support and implementation in a manner that matches its temporal mission to stand-up a market-driven commercial HALEU production capacity in the United States. Therefore, the DOE should design programmatic support with its exit strategy clearly in mind.

A successful programmatic structure would leverage familiar, proven approaches for commercial financing of enrichment and chemistry services capacity, such as firm contractual offtake agreements as discussed in Question 3 and 4. Tools and programmatic approaches should be structured to allocate technical and financial risk appropriately, as introduced in Question 5.

Absent DOE resources and assurances, commercial investment in industrial HALEU production facilities will not occur in the timeframe necessary to support the timelines defined by the HALEU Availability Act. In order to accelerate commercial investment, DOE will need to actively bridge key uncertainties. The DOE has a range of tools that can be applied for this purpose, including Cost-Share support to advance elements of industrial readiness such as design and licensing. However, from an industrial perspective, Cost-Share resources alone are unlikely to be sufficient to finance new industrial capacity. Additionally, a predominantly Cost-Share approach would introduce schedule, delivery, and cost risks for the DOE that could otherwise be borne by industry. As the principal policy mechanism for assuring HALEU availability, the DOE should provide programmatic support for firm offtake commitments through take-or-pay contracts, establishment of a HALEU Bank, or some combination that provides the familiar economic basis for industrial investment.

(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?

There are no technical or licensing challenges to the transport of HALEU. The design and licensing of packaging for transportation is driven by the form of the material: oxide, metal, or salt mixture. Orano is developing packages that can accommodate commercial quantities of all of these forms with enrichments from 5% to 20% uranium-235.

Within the constraints of licensing and manufacturing lead-times, the availability of this fleet of packages is largely a function of commercial demand for its utilization. The manufacture of packages is unlikely to proceed at commercial risk, but would be responsive to firm commitments.

Transportation infrastructure should be an enabler of competition, innovation, and redundancy. To accelerate availability of this infrastructure, the DOE should support the development of this flexible, technology-neutral transport fleet. Support can be provided through Cost Sharing for licensing, and through mechanisms providing for firm utilization commitments that secure manufacturing capacity and finance the fabrication of packages.

(12) Questions specific for transportation packaging companies:
(i) What actions, either federal or non-federal, might help incentivize the development and delivery of a new or modified 30-inch cylinder? Please discuss incentive amounts and incentive areas (design, licensing, certification, overpack re-certification, etc.) as appropriate that would be most helpful to accelerate the delivery date.

(ii) If your company were to receive an order for a 30-inch transportation package that is certified by NRC to contain enriched uranium hexafluoride up to 19.75 wt. percent Uranium-235, what do you expect would be the earliest delivery date possible? What do you anticipate would be its maximum loading?

Orano is developing a portfolio of packages and is currently licensing the DN30-20 packaging system, with a maximum capacity of 1271 kg UF6. Completion of this licensing process is targeted for the second half of 2022.

Assuming firm commercial orders or utilization commitments are in place prior to package fabrication, the anticipated manufacturing schedule would deliver an initial fleet of 20 packages within 18-24 months after completion of licensing and would require clear and early signals for the planning for allocation of manufacturing load. DOE should support paths which accelerate deployment of packaging solutions supporting all market participants.

(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?

Based on Orano's experience with operating enrichment and conversion facilities, we note the following benefits of co-locating deconversion and chemistry services with enrichment capacity for initial HALEU production capacity:

- Co-location of enrichment and deconversion in solid form units mitigates proliferation risks (non-proliferation by design)
- Co-location offers opportunities for licensing timeline reduction through interoperable systems
- Co-location defers immediate need for a fleet of licensed transportation packages
- Deconversion processes must also be conducted in a facility with appropriate levels of physical security, so co-location with enrichment capacity leverages security costs
- Co-location would clearly help to minimize the cost of the HALEU product

Ultimately, packaging and transportation infrastructure will be critical for enabling additional scale and redundancy of production capacity across multiple HALEU production and utilization facilities.

(14) What factors affect the ability of U.S. uranium producers to provide uranium for advanced reactor fuel? Please indicate the importance of such factors and how they may be addressed.

Uranium is a global commodity market. Nuclear facilities around the world make uranium procurement decisions based on factors such as price, geopolitical risk, and supplier diversification. Uranium oversupply worldwide coupled with diminished demand has resulted in a depressed market, an environment not conducive to further mine investment.

The deployment of advanced nuclear systems at the scale envisioned by the Nuclear Energy Institute's assessments will require significant, sustained quantities of uranium supply. The scale of uranium demand envisioned would have a strong impact on the overall pricing dynamics for uranium, which would favorably impact decisions to proceed with investments in uranium production worldwide.

We believe that through successfully establishing the advanced nuclear market, demand for all front-end products will naturally increase. In this situation, U.S. uranium miners, if economically competitive, will almost certainly be able to compete to supply these quantities to convertors and enrichers to assist in the production of HALEU.

Regulatory Issues

(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?

Technical and regulatory barriers are understood and surmountable, as discussed in response to Question 3. The NRC's requirements are understood for the licensing of HALEU production capacity to include facilities for enrichment along with deconversion, though each of these licensing processes will require the detailed definition of operational scope and production specifications. It is of utmost importance to have a smooth licensing process completed on-schedule in order to meet DOE targets for HALEU availability. As previously noted, solidification of industry specifications and DOE programmatic requirements are likely to impact finalization of any commercial designs submitted for NRC licensing, and should be defined as soon as practicable.

The DOE should leverage its interagency leadership position to facilitate expeditious usage of international technologies from NPT signatories to support accelerated HALEU production timeline. Further, DOE should engage through international forums and processes to drive harmonization between selected international standards and domestic requirements, including definition of IAEA warranties.

(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).

Additional criticality benchmark data will not be essential for licensing HALEU production capacity. However, NRC benchmarking data could serve as a valuable input in final design parameters.

Further, in assessing and benchmarking the broader commercial nuclear ecosystem, the NRC should identify gaps and support harmonization between international standards and U.S. domestic requirements. For example, international standards currently prevent the transportation of LEU+ assays utilizing existing 30B canisters, potentially limiting the depth of accessible LEU+ supply. As discussed in Question 7, LEU+ could offer certain economic advantages over LEU and, if so, should be sourced from the competitive global market, subject to existing statutory limitations.

(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?

The backend of the fuel cycle for advanced reactors must be considered as early in the design process as possible to account for the potential economic, technological, and regulatory challenges that it presents. The business cases for advanced reactor systems will need to account for backend requirements, with a wide range of potential scenarios to contemplate for each reactor type (with numerous additional scenarios possible with recycling and the combining of multiple reactor types). Solutions to challenges include, but are not limited to:

- Recycling of UNF to reduce potential interim storage issues of UNF and produce waste form suitable for repository disposal
- Double packaging of SNF (inner package acts as cladding equivalent)
- Health monitoring of internal conditions within casks/canisters used for dry interim and potentially extended storage of UNF/SNF
- Conditioning of SNF in preparation for storage, transportation, and/or disposal
- Specifically designed packages for extended interim storage and/or disposal of SNF
- Aging management programs with inspection systems, repair/mitigation, repackaging, etc.
- High density storage systems
- Transportation systems for higher-enriched fuels

(18) What other legal, funding, and other issues should be addressed to best enable the development of a HALEU availability program and promote private sector deployment of domestic HALEU production capacity?

HALEU availability, as envisioned by the 2020 Energy Act, requires the urgent organizational leadership of the Department of Energy in defining requirements and accelerating industrial readiness for installation of production capacity. The Congress should ensure that appropriate resources are available for this activity.

In order to leverage commercial technology and investment, firm offtake mechanisms must be defined and accessible for HALEU production capacity. The DOE and the Congress should work to design, authorize, and fund these mechanisms, such as a HALEU Bank, that can provide the commitments necessary to ensure investment in commercial production capacity. The assured availability of programmatic funding and resources will be foundational to success. Congress should be sure to direct funds in a manner that best assures commercial availability without placing undue technology risk on the taxpayer.

Financial Barriers

(19) Please describe the financial challenges associated with developing a sustainable commercial fuel supply chain for HALEU. Specifically, what are the challenges related to the acquisition of funds for investment in HALEU production infrastructure? How might these challenges be mitigated?

There are familiar, proven financing paths for bringing new enrichment and conversion capacity online, as detailed in prior responses. The market for HALEU production does not meet traditional conditions for investment, due primarily to the significant demand uncertainties, which are well beyond the risk tolerance for commercial investment. As noted previously, tools, authorities, and resources are available to the DOE and must be employed, with the support of the Congress, to smartly target and mitigate this investment risk. This is best achieved through DOE's guarantee of production offtakes, as discussed in Question 4.

It is important to note that investment in commercial HALEU production capacity will have important, beneficial impacts throughout the environment for financing new advanced nuclear projects. Assured HALEU production capacity is a force-multiplier in the organization of capital for advanced reactors. The availability of stable, U.S.-based HALEU production capacity would satisfy a key investment condition for HALEU-dependent reactor technologies, opening access to capital to enable greater scale in commercial deployments. Similarly beneficial impacts from increased capital access would extend to the dedicated manufacturing supply chain directly supporting construction of new HALEU production capacity. This drives needed commercial capital toward the accelerated deployment of needed decarbonization applications.

Over the years, the U.S. has seen a decline in active, qualified suppliers as once-qualified nuclear suppliers have let their certifications lapse based on lack of opportunity or cost to attain/maintain. The DOE should support U.S. companies' efforts to attain or regain nuclear supplier quality certifications, such as NQA-1, ASME-N, and NPT stamp. These commercial qualification standards will be required for a healthy, responsive supply chain.

Human Resources

(20) What are the human resource-related considerations related to the buildout of commercial HALEU production? Are there specific recruitment and/or training challenges that must be overcome? What types of skillsets are needed to develop and deploy the domestic commercial production of HALEU? Would this increase the number of union jobs?

The design, construction, and operation of new commercial HALEU production facilities will create a range of direct jobs, durable career opportunities, and encourage further development of the U.S. advanced manufacturing supply chain. These direct jobs would be complemented by indirect job creation and regional economic growth opportunities that accompany industrial development and deployment of new, state-of-the-art technologies.

Orano is an experienced industrial operator, with a firm grasp on hiring and training a workforce to deliver all of the skillsets required for commercial HALEU production. In accelerating workforce readiness, the DOE should partner with industry where possible to increase accessibility to training and certification programs, leveraging local community colleges and trade schools to ensure an inclusive workforce pipeline.

Other

(21) Are there additional considerations or recommendations, including the timing of various actions, that should be considered with respect to key challenges to HALEU availability for civilian domestic research, development, demonstration, and commercial use in the United States?

None. See topics as previously addressed in Questions 1 - 20.

3. Contact Information

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Orano USA, a U.S. subsidiary of Orano, is a leading supplier of nuclear fuel materials, nuclear materials transportation, used nuclear fuel management, and decommissioning, decontamination, and radwaste treatment solutions to U.S. commercial and federal customers.

Orano USA, through its subsidiary Orano Med in Texas, is developing nuclear medicine cancer treatments using targeted radio-immunotherapy, with its first drug undergoing FDA-authorized clinical trials.

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