Non-Proprietary

February 14, 2022

Via Electronic Submission to rfi-haleu@hq.doe.gov

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

Subject: **Response to RFI Regarding Planning for Establishment of a Program to Support the Availability of HALEU for Civilian Domestic Research, Development, Demonstration, and Commercial Use (86 Fed. Reg. 71055 (Dec. 14, 2021))**

Dear Dr. Vega:

Urenco USA Inc. appreciates the opportunity to submit these comments in response to the U.S. Department of Energy's 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.

Urenco USA Inc. is the corporate parent of Louisiana Energy Services, LLC ("LES"), a Delaware limited liability company, which is the licensee and operator of Urenco USA ("UUSA"), also known as the National Enrichment Facility. LES has a license from the U.S. Nuclear Regulatory Commission ("NRC") to construct and operate UUSA, the only commercial facility in the United States producing enriched uranium to fuel commercial nuclear power plants. UUSA is licensed to produce a total annual output of 10 million Separative Work Units per year ("SWU/year") and is authorized to possess depleted, natural and enriched uranium. Located in southeastern New Mexico, UUSA reflects an investment in U.S. manufacturing of more than $5 billion. UUSA is currently capable of meeting roughly one-third of annual demand for uranium enrichment services from U.S. utilities, based on present capacity of approximately 4.6 million SWU/year, and is proud to facilitate zero carbon electricity generation for consumers.

Urenco USA Inc. is part of the Urenco Group, which is the world's leading supplier of uranium enrichment services and fuel products. The Urenco Group has more than 50 years of experience designing, licensing, constructing and operating uranium enrichment facilities. In addition to its site in New Mexico, the Urenco Group operates three other gas centrifuge enrichment facilities in the United Kingdom (Capenhurst), the Netherlands (Almelo) and Germany (Gronau), for a total capacity of 18.1 million SWU/year. The Urenco Group also provides products and services beyond enrichment and fuel, including services relating to the management of nuclear materials for DOE and others, as well as the production of

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stable and medical isotopes in support of nuclear medicine, research and industrial applications. The Urenco Group also participates in important non-proliferation projects with DOE.

Urenco USA Inc. supports and stands ready to assist the Department of Energy ("DOE" or "the Department") as it implements the Energy Act of 2020 and develops its HALEU Availability Program. Urenco USA Inc. looks forward to the opportunity to work with DOE and members of the HALEU Consortium to assist in securing adequate domestic HALEU supplies to support existing reactors, support the development and deployment of advanced nuclear reactors, and meet the needs for HALEU of civilian research reactors and medical isotope production facilities. Urenco USA Inc. provides an overview followed by specific responses to DOE's RFI questions below.

Overview

High-assay low-enriched uranium is needed for a wide range of applications across the civilian nuclear industry. Currently, the existing nuclear fleet uses fuels enriched to just below 5% uranium-235 ("U-235"), but in the coming years they will also use fuels enriched between 5% and 10% U-235, frequently referred to as Low-Enriched Uranium Plus ("LEU+"), to improve the safety and efficiency of their operations. As the Department describes in the RFI, civilian research reactors and medical isotope production facilities, as well as many types of advanced reactors and fuels currently being designed, also have a need for higher-assay fuels, enriched to between 10% and 19.75% U-235 ("HALEU").[1] As discussed in the RFI, there is currently a very limited capacity to provide HALEU in the United States, either from DOE or commercial sources, and a robust domestic HALEU production capability will be essential to meet the growing needs for HALEU for civilian domestic research, development, demonstration, and commercial use.

Urenco USA Inc. strongly supports and looks forward to partnering with DOE to establish its HALEU Availability Program. Urenco USA Inc. is already pursuing the production of higher assay fuels to meet current and future customer needs taking a two-phased approach:

1. As part of the first phase, and in response to requests from utilities in the United States, LES is currently pursuing amendments to its license at its site in New Mexico to enrich uranium between 5.5% and 10% U-235. For the existing fleet of light water reactors (LWRs), fuel designs using LEU+ promise to increase efficiency and improve safety performance. As discussed below, LES anticipates having the ability to provide and deliver LEU+ as uranium hexafluoride ("UF_6") potentially as early as 2024.

2. As part of its second phase, and subject to firm customer commitments, we are also pursuing the design, licensing, construction and operation of a facility at the UUSA site in New Mexico to produce HALEU. Although existing enrichment capacity (designed and licensed as a Category III facility) cannot be re-purposed to produce HALEU, a separate, relatively small, dedicated facility can be co-located with the existing enrichment capacity at the UUSA site to produce HALEU, with

[1] In this response, Urenco USA Inc. uses the term "LEU" to mean fuel enriched below 5% U-235, "LEU+" to mean fuel enriched to between 5% and 10% U-235, and "HALEU" to mean fuel enriched to between 10% and 19.75% U-235. This definition aligns with the definition of a Category II facility. *See* "The Convention on the Physical Protection of Nuclear Material"; IAEA INFCIRC/274 Nov. 1979.

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the ability to use feedstock generated by the existing facility and to rely on the site's existing infrastructure. For this second phase, and as further discussed below, a conceptual design of an enrichment facility is being developed for the UUSA site that would produce UF_6 enriched up to 19.75% U-235.

The UUSA site in New Mexico is ideally positioned to host a HALEU production facility. LES' current NRC license to operate extends through 2040. In addition, the site has adequate physical space, a trained workforce, and community support at the state and local levels. As a member of the Urenco Group ("Urenco"), the UUSA site also has access to over 50 years of operating experience, expertise and data relating to the operation of enrichment facilities and their infrastructure. The development of a HALEU facility at the existing UUSA site would leverage that existing infrastructure and experience.

Specific Responses to DOE's RFI:

Establishment of a HALEU Consortium & Market Development

Question 1: 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.

Urenco USA Inc. recommends that the consortium to be established pursuant to the Energy Act of 2020 to partner with DOE and support the availability of HALEU for demonstration of advanced reactors and commercial use include: advanced reactor developers and operators, uranium producers, converters, enrichers, firms with uranium chemistry expertise, fabricators, and developers of storage and transportation package solutions.

Urenco USA Inc. would like to be a member of the HALEU Consortium, as well as to partner with DOE to provide enrichment services and assist in developing a domestic HALEU production capability to support research, demonstration, and deployment of advanced reactors, in addition to supporting research reactors and the production of isotopes for medical and industrial applications. UUSA is the only U.S. enricher in the United States of uranium for civil nuclear power plants and one of the few NRC licensees that can hold and store nuclear material for the U.S. mining and conversion industries, utilities and the DOE. UUSA is also a vital member of the domestic nuclear fuel cycle, and already supports DOE in several key activities, including the storage and management of UF_6 at its site. As noted above, the UUSA site has access to over 50 years of design, operating experience, expertise and data relating to the operation of enrichment facilities. Importantly, the UUSA site can rely on already proven centrifuge designs and well-established supply chains for centrifuges and associated equipment needed to construct a HALEU production facility.

Urenco USA Inc. is capable of assisting DOE in serving a broad community of users who stand to benefit from HALEU supply. This community of users includes: i) research and test reactors, including reactors fueled by DOE in the United States and abroad; ii) advanced reactors; iii) advanced fuel designs including

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Accident Tolerant Fuels for existing light water reactors; and iv) producers of targets for medical isotope production and other industrial uses.

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Question 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.

Establishment by DOE of a HALEU Availability Program and related clean energy infrastructure investments would support expanded access to clean, reliable energy supplies, including for individuals in disadvantaged communities that may be disproportionately impacted by higher energy costs. Such investments can also directly support economic growth in the communities and regions where the facilities in which DOE is investing are located, including disadvantaged communities that may benefit from direct employment at the site and economic and other support for communities resulting from those investments.

Question 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.

As DOE's RFI describes, there is currently a very limited domestic capability to produce HALEU in the United States to support advanced reactor demonstration and commercial deployment. To ensure adequate HALEU supplies going forward, a complete and sustainable commercial HALEU fuel cycle would include five fundamental capabilities:

1. Increased primary uranium production to support incremental demand for HALEU fuels;

2. One or more uranium conversion facilities producing UF_6 for enrichment facilities;

3. One or more uranium enrichment facilities producing HALEU in the form of UF_6;

4. One or more deconversion facilities to convert HALEU UF_6 into the chemical forms needed for advanced fuel fabrication such as uranium tetrafluoride ("UF_4"), uranium metal, or oxide, as appropriate for different reactor designs and fuel types; and

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5. One or more fabrication facilities that can manufacture the specific fuel types required by the various reactor and fuel designs.

All of the above needs to be supported by the availability of certified containers for the storage of different forms of HALEU and certified packages to enable the transportation of the material.

We discuss specific considerations relating to each of the five fundamental capabilities below:

1. *Primary Uranium Production*

Although there are currently adequate global supplies of uranium for the existing LWR fleet, inventories continue to be drawn down and uranium production has become highly concentrated, particularly in Kazakhstan which is politically unstable, as shown by recent events. U.S. uranium production has fallen to nearly zero and large mines in Canada and other countries have also shuttered or been idled since the Fukushima accident. Adequate supplies of newly produced uranium from the U.S. and politically stable and allied nations must be available in the long-term to support domestic HALEU production.

2. *Conversion Facilities*

Natural uranium in the form of UF_6 is required by all commercially deployed uranium enrichment technologies. There are currently only two uranium conversion facilities producing natural UF_6 outside of Russia and China, one in Canada and the other in France. ConverDyn - the sole domestic uranium conversion facility - is currently in the process of restarting, but at a maximum capacity much lower than its historic output. As UF_6 inventories continue to be drawn down, HALEU production together with continued production of LEU will likely require incremental expansion of existing conversion facilities and/or development of new conversion facilities.

3. *Enrichment Facilities*

The technology needed to enrich uranium for the production of HALEU already exists and is being used at commercial scale; there is no need to research or test or demonstrate how to build a commercial-scale HALEU facility. Supply chains for centrifuge components and associated equipment are well established, and the large and complex facilities required to assemble centrifuges already exist at the UUSA site. As discussed further below, Urenco is developing a conceptual design for the UUSA site that would produce UF_6 between 10% and 19.75% U-235, and engineering work is ongoing on both the basic and reference designs required for a license application and final investment decision.

The most significant barriers for the development of enrichment facilities are the lack of business and regulatory certainty regarding the commercial market and the timing and need for HALEU. In particular, the reactors under development are currently subject to NRC review and licensing and the timing for these processes and reactor deployment is not fully known. Nor are the specific quantities and forms of HALEU that will be needed for the reactors that will be ultimately deployed yet known. As a commercial entity, Urenco USA Inc. cannot commit to either complete a final design for, submit a license application for, or

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construct and operate a HALEU enrichment facility absent firm contracts to purchase HALEU as UF_6, or in other desired forms.

With respect to timing for licensing and constructing a HALEU facility, a HALEU facility for enrichment between 10% and 19.75% U-235 would fall under NRC physical security requirements for Category II special nuclear material (the current license at UUSA is for Category III special nuclear material).[2] For the UUSA site, Urenco USA Inc. estimates 24 to 36 months, depending on the availability of resources, would be needed for design activities before license application. Assuming NRC has clearly defined requirements for Category II facilities, Urenco USA Inc. anticipates that review and approval of a HALEU enrichment capability at the UUSA site should be feasible within a 24 to 30 month period, depending on prioritization and the availability of resources. We estimate that if detailed design, site permitting and contractor selection were undertaken during the NRC application review process UUSA could construct, commission and start up a HALEU production facility within 24 months of NRC license approval. This estimate reflects our actual construction experience for the most recent construction phases at the UUSA facility.

4. Deconversion Facilities

Similar to LEU fuels, there will be a need to deconvert the UF_6 produced at the HALEU enrichment facility into a chemical form that is compatible with a specific fuel fabrication process for use in different reactors and applications. Deconversion of UF_6 to another chemical form could be done at a new facility located at the UUSA site, at a separate site, or at an advanced reactor fuel fabrication facility site. Under appropriate business and regulatory conditions, the UUSA site could accommodate third party de-conversion and/or fabrication facilities. Movement of HALEU in the form of UF_6 would require a transportation package certified to move UF_6 from the HALEU facility to the de-converter or fuel fabricator on public thoroughfares. Today, the most prominent forms of HALEU being considered by reactor designers and their fabricators for their advanced concepts are: UF_4, uranium metal, U_3O_8 and UO_2.

To develop the full HALEU fuel cycle capability, there will be a need to demonstrate deconversion processes at a commercial scale. Deconversion of UF_6 enriched up to between 10% and 19.75% U-235 would also require a Category II facility and there would be similar security and safeguard requirements to those of the enrichment facilities. In addition to the criticality safety requirements that would have to be addressed for the enrichment facility, the industrialization of the chemical reactors that will transform UF_6 into the desired chemical compound needs to be addressed. Today, most of these compounds are only produced in a laboratory, or at small scale, and not in a modern industrial facility that can provide significant quantities through safe, continued operations. Accordingly, there is a need to scale up the existing technologies to develop a commercial scale deconversion process for converting UF_6 to its desired forms.

[2] These requirements are currently being reviewed by NRC. NRC has recently determined no near-term updates to regulations or policies for Material Control and Accounting are necessary for facilitating HALEU licensing and commercial availability, but is updating its guidance which the Commission expects to finalize by the spring. *See* NRC report titled "Preparedness for High Assay Low Enriched Uranium Availability," available at https://www.nrc.gov/docs/ML2132/ML21323A151.pdf at p. 1; *see also* 12-14-21 Letter to Honorable Patrick Leahy, et al., submits the report on Preparedness for High Assay Low Enrich Uranium Availability (nrc.gov). NRC is also is determining whether any near-term updates to its regulations, policies or guidance are needed for physical security plans related to facilities with HALEU. *See* NRC report at pp. 3-4.

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Design and licensing of HALEU deconversion facilities should be undertaken concurrently with the development and licensing of HALEU enrichment facilities.

5. *Fabrication Facilities*

Previously announced programs to develop fabrication techniques are planned, underway or already established at DOE and private sector laboratories or sites. In addition, two U.S. fuel fabrication plants are already licensed by the NRC to use higher enrichments: the Nuclear Fuel Services facility in Erwin, Tennessee and the BWXT Nuclear Operations Group facility in Lynchburg, Virginia. These facilities are employed in support of the U.S. Naval Reactors program but also support the U.S. Government, including the National Nuclear Security Administration ("NNSA") in its existing Highly Enriched Uranium down-blend activities and the production of research reactor fuel. These currently-operating facilities demonstrate the viability of licensing and operating at higher enrichments.

While enrichment and fuel fabrication facilities are held to similar regulatory requirements, Urenco USA Inc. is not in a position to speak directly for the fabrication community. The time required to license and construct fabrication facilities will likely largely depend on whether existing fabrication facilities can be utilized or whether greenfield sites are proposed, but our hope is that the NRC would be able to review, approve and issue other fuel cycle licenses in relatively similar time frame as for enrichment activities.

Potential Co-location of Facilities

Urenco has consulted with other industrial partners relating to de-conversion services, fabrication and logistics. Urenco and its potential industrial partners have concluded that a solution which avoids or reduces transport of intermediate forms of HALEU on public highways is to co-locate chemical conversion and potentially fuel fabrication facilities with the HALEU production facility. In addition to reducing the number of transportation steps and packaging requirements, it would also reduce the time and burden associated with new licensing reviews, and leverage infrastructure and security costs. Urenco USA Inc. is willing to consider hosting such capabilities at its New Mexico site under appropriate lease and/or operating agreements.

Trade Related Considerations

In addition to the above, there are also trade related considerations that present a challenge to the development of a domestic HALEU production capability. In particular, companies in the domestic nuclear fuel supply chain in the United States currently face significant competition from Russian and Chinese state-owned enterprises with respect to the mining, conversion and enrichment of uranium. They will continue to face such competition for the supply of HALEU, including from Russian state-owned enterprises.

Urenco USA Inc. has aligned with uranium production and conversion services companies operating in the United States to promote a strong domestic nuclear fuel supply chain, including through Urenco USA Inc.'s support for the extension of the Russian Suspension Agreement ("RSA"). Implementation of the RSA and the Domenici Amendment, extended and codified in 2020, will play an important role in developing a robust domestic fuel cycle for HALEU supplies. Any long-term facilitation or acceptance of Russian HALEU

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fuel supplies by U.S. government agencies inconsistent with the RSA and Domenici Amendment will be a significant threat to investment in domestic fuel cycle facilities to produce HALEU.

Question 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)?**

Even without advanced reactors, there is a current need for HALEU for research reactors and medical isotope production. In 2017, NNSA provided projections for its future needs for HALEU for research reactors and molybdenum-99 production facilities inside and outside the United States. DOE/NNSA projected that the need would be 3 to 7 metric tons of uranium ("MTU") annually between 2019 and 2034.[3]

Assuming successful deployment of advanced reactors currently under development, the Nuclear Energy Institute ("NEI") has surveyed potential needs for HALEU enriched to between 10.9% and 19.75% U-235 for advanced reactors being developed in the United States and Canada. The NEI survey's long-term estimates are comparable to the long-term estimates published in a December 2021 report by Idaho National Laboratory (INL/EXT-21-64913): "Estimated HALEU Requirements for Advanced Reactors to Support a Net-Zero Emissions Economy by 2050," which estimates a rapid annual demand growth from near zero in 2030 to 520 MTU/year in 2050.

- **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?**

Actions taken by the government to support the development of a HALEU related market would help to build confidence for commercial entities in the private sector. To the extent the Federal government incentivizes and supports development of advanced reactors, this would serve as an effective mechanism for helping to support development of a domestic HALEU fuel supply infrastructure. Given the uncertainties and the risks associated with the development and deployment of any new technology, and as noted above, as a commercial entity, Urenco USA Inc. cannot commit to either complete a design for, submit a license application for, or construct and operate a HALEU enrichment facility absent firm contracts to purchase HALEU. The Federal government could further enable the necessary investments by aggregating the HALEU demands for existing and future research reactors and medical isotope production facilities with other needs of advanced reactors.

[3] *See* Amendment to NNSA RFI for Supply of Enriched Uranium, Questions and Answers, FRI DE-SOL-0008552 available at https://www.fedconnect.net/FedConnect/default.aspx?ReturnUrl=%2ffedconnect%2f%3fdoc%3dde-sol-0008552%26agency%3ddoe&doc=de-sol-0008552&agency=doe . At that time, DOE/NNSA additionally projected that starting in 2040 there would be a total annual requirement for research reactors and medical isotope production of approximately 9.7 to 10.7 MTU enriched to 19.75% U-235. The development of a domestic HALEU capability could assist DOE/NNSA in meeting its research reactor and medical isotope production needs and long-term planning.

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Costs for an enrichment facility will depend on a wide range of factors, such as the capacity, security, storage and transport requirements and potential co-location of deconversion facilities. Urenco currently estimates that the costs to build a HALEU enrichment facility at the UUSA site would be in the range of $200 million to $300 million (preliminary). This estimate is associated with the design, licensing and construction costs for such an enrichment facility. This does not include costs associated with operations and maintenance of the facility, or waste management and decommissioning costs.

- **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?**

Investment by DOE in the HALEU Availability Program would promote additional investment in communities that would benefit from such investment and from related economic growth and job creation. As DOE makes such investments it should consider appropriate protections to address potential environmental impacts on affected disadvantaged or low-income communities. As DOE determines the appropriate structure for its HALEU Availability Program and community impact, it should also consider incentivizing domestic companies that have established community presence and are actively engaged in promoting equity within their workplace and communities. Please see responses to Questions 2 and 13 addressing siting and energy justice issues.

Question 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?**

The U.S. Government can facilitate the development of HALEU supplies by continuing to take actions that will create a commercial market for HALEU. This includes continuing to fully implement DOE's Advanced Reactor Demonstration Program and other research and development programs that will enable the deployment of advanced reactor technologies, including for small modular and micro-reactors. The U.S. Government should also continue supporting the financing of advanced nuclear energy projects through the DOE Loan Program Office to facilitate innovative nuclear energy technologies through loans and loan guarantees. Additionally, DOE should also continue to fund hydrogen demonstration projects at existing reactors, including through implementation of the recently enacted bipartisan infrastructure legislation providing for a regional hydrogen hub to demonstrate the production of hydrogen from nuclear energy.

Additional actions that would facilitate creation of a commercial HALEU market include the following:

I. To support development of a commercial HALEU market, DOE should fully implement the Energy Act of 2020. This includes taking steps, subject to available appropriations, to acquire or provide HALEU supplies for advanced reactors, research reactors, and medical isotope production through private-public partnerships, long-term contracts, a fuel bank, and/or other contractual mechanisms.

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II. The Department may also want to consider cost-sharing to fund the development of HALEU facilities; while such an approach does not eliminate the need for long-term contracts to support investment in HALEU facilities, it can mitigate the risks. *See* response to Question 10 below for further discussion of specific types of contracting mechanisms and cost-sharing partnerships.

III. The Department may also want to consider the potential for government guarantees for private contracts for HALEU supplies to the extent it may be practicable under existing or future legislation.

To the extent the U.S. makes purchases as part of its HALEU Availability Program or pursues cost-sharing approaches, DOE should use competitive, transparent processes to support development of a commercial market for HALEU. In developing its HALEU Availability Program, DOE should consider those actions which would be most cost-effective for creating a commercial market, seek to leverage existing domestic facilities and capabilities, and pursue cost recovery mechanisms where applicable consistent with the Energy Act of 2020, or future legislation.

To support the creation of a commercial market, DOE should also help facilitate timely regulatory and licensing processes for the licensing of commercial HALEU production facilities. Pursuant to the Energy Act of 2020, NRC has recently provided a report to Congress indicating that the Commission does not anticipate near-term updates will be necessary to its regulations or policies for material control and accounting to facilitate HALEU licensing and commercial availability. NRC also advises that it is considering whether any updates to its regulations, policy or guidance are needed for physical security plans related to facilities with HALEU. Urenco USA Inc. recommends that DOE and NRC continue to collaborate to ensure timely regulatory and licensing processes, including by ensuring that appropriate resources are available to manage timely and contemporaneous reviews.

Finally, the DOE should use whatever limited resources are available to promote development of a HALEU fuel cycle through financial support for processes and technologies that are not yet fully commercialized, *i.e.* deconversion, fabrication and HALEU packaging. Uranium mining, conversion and enrichment technologies are already mature and widely commercialized and while investment decisions in those existing processes may require government resources, the development of the technologies themselves does not require additional U.S. Government financial support.

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

The private sector can facilitate HALEU availability by designing, licensing, constructing and operating the facilities needed for the production of HALEU, including by leveraging existing facilities in areas with community support. As part of its initial phase for producing higher-assay fuels, LES is planning to amend its license and make modifications to its existing Category III facility to produce UF_6 enriched from 5.5% to 10% U-235. For the existing fleet, LEU+ can increase efficiency and performance design basis, widen existing safety margin for nuclear plants, extend operating cycles between refuelling outages, allow for longer-lived fuel with increased enrichment (less replacement fuel during outages), and reduce nuclear plant operational and maintenance costs. LES anticipates having the ability to provide LEU+ potentially as early as 2024. This project is supported by Urenco's commercial contracts and relies on the long-term strategic partnerships Urenco has established with its customers. Urenco believes that long-term

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commitments to support advanced reactors would facilitate the creation of a HALEU supply chain, just as it has with LEU+.

To meet future needs, and as part of its second phase for producing higher assay fuels, Urenco is pursuing the design, licensing, construction and operation of a facility at the UUSA existing site to produce HALEU. As noted above, a conceptual design for an enrichment facility is being developed for the UUSA site which would enrich UF_6 between 10% and 19.75% U-235. The new HALEU facility would utilize Urenco's existing proven gas centrifuges that currently produce LEU. As discussed in response to Question 7, the separative work necessary to increase U-235 concentration from 5% to 20% is not large; the footprint of a HALEU production facility is similarly not large (on the order of 50,000 square feet) and could easily be accommodated on the existing approximately 2-square miles of the UUSA site. The co-location of HALEU production facility with an existing enrichment facility would have many economies of scale and would take advantage of pre-existing investments, including facilities needed to assemble, test and install centrifuges. In pursuing development of a HALEU production facility at its site, UUSA would be able to rely on existing site characterization data, utilities, plant processes, safety control system, all of which are already familiar to NRC, while ensuring that additional site-specific requirements for Category II operations are met in full.

The UUSA site in New Mexico is ideally positioned to partner with DOE and to host a HALEU production facility on its site. As noted above, UUSA's current NRC license to operate extends through 2040, the feedstock for the HALEU facility would be generated at the existing site reducing the size and footprint of the facility and related costs, and minimizing the need for transport of feed material. Additionally, the UUSA site has adequate physical space, a trained workforce, and community support at the state and local levels.

Question 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?

Near term action in developing a viable HALEU fuel cycle, including availability of appropriate containers and packaging, is required to ensure that lack of fuel does not hinder the development and possible broad-scale deployment of advanced reactors and advanced fuel types. Development of a domestic HALEU capability will also be needed for operation of existing research and test reactors.

Commercial investment in the fuel cycle for HALEU will not be made on a speculative basis; that is, investment in the optimized minimum economic scale for fuel cycle infrastructure will not be made without sufficient long-term firm purchase agreements for HALEU. Ordinarily, this would mean that commercial sources of HALEU would not be available until well into the second phase of demand when aggregate fuel demand from reactor operators would support a sufficiently robust set of contractual commitments to buy HALEU, but even then spreading the high fixed capital investment cost over limited volume of sales would burden early commercially deployed advanced reactors with high fuel costs. For this reason, U.S. Government initiatives and investments to accelerate development of a domestic HALEU commercial market will be critical to timely establishing a robust domestic HALEU capability. This applies to supporting the development and deployment of advanced reactors through enabling policies, and to both the enrichment process and the chemical conversion of the enriched UF_6 into the chemical forms needed for fuel fabrication.

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Companies making investments in HALEU facilities need to be assured a reasonable rate of return on those investments. Early consumers of HALEU will not want to pay for the entire capital investment required for HALEU facilities over few deliveries. For these reasons, and as discussed above in response to Question 4, to justify an investment in a HALEU facility, Urenco USA Inc. needs market signals for sustainable demand and long-term contracts for purchase of HALEU. Long-term firm contracts (where the length is informed by accounting depreciation schedules for buildings and equipment) allow for both reasonable returns and reasonable prices.

Question 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, UF_6, etc.) in your response.

The pricing for HALEU will be a function of the prices of converted natural uranium, the price of SWU to generate LEU feedstock for a HALEU facility, the recovery of capital investment in the fuel cycle facility or facilities which include enrichment and carry out the de-conversion process, the cost of transport package development and transportation, the cost to decontaminate and decommission HALEU facilities, the cost to manage and dispose of incremental depleted uranium associated with HALEU production, operating costs, and a reasonable economic return. Similar to today's sales of HALEU by DOE to the research reactor community, Urenco USA Inc. anticipates that the pricing mechanism for HALEU will be implemented in the market as value-added pricing "$/kgU", as opposed to a price for processing services expressed as "$/SWU" for LEU and LEU+. This reflects the incremental capital investment needed to license, build, secure and operate a HALEU facility, the output of which will require a relatively small amount of separative work.

As depicted below, over 90% of the separative work necessary to produce HALEU enriched at 19.75% U-235 is consumed to produce LEU+ (that is, uranium enriched to less than 10% U-235). To optimize production and keep new investment costs as low as possible, existing Category III facilities could be used to generate LEU, and in the near future LEU+, feedstock for what would then be a much smaller Category II HALEU production facility. While the development of a HALEU facility will require significant investment, the ability to leverage existing facilities will allow for the most cost-effective production.

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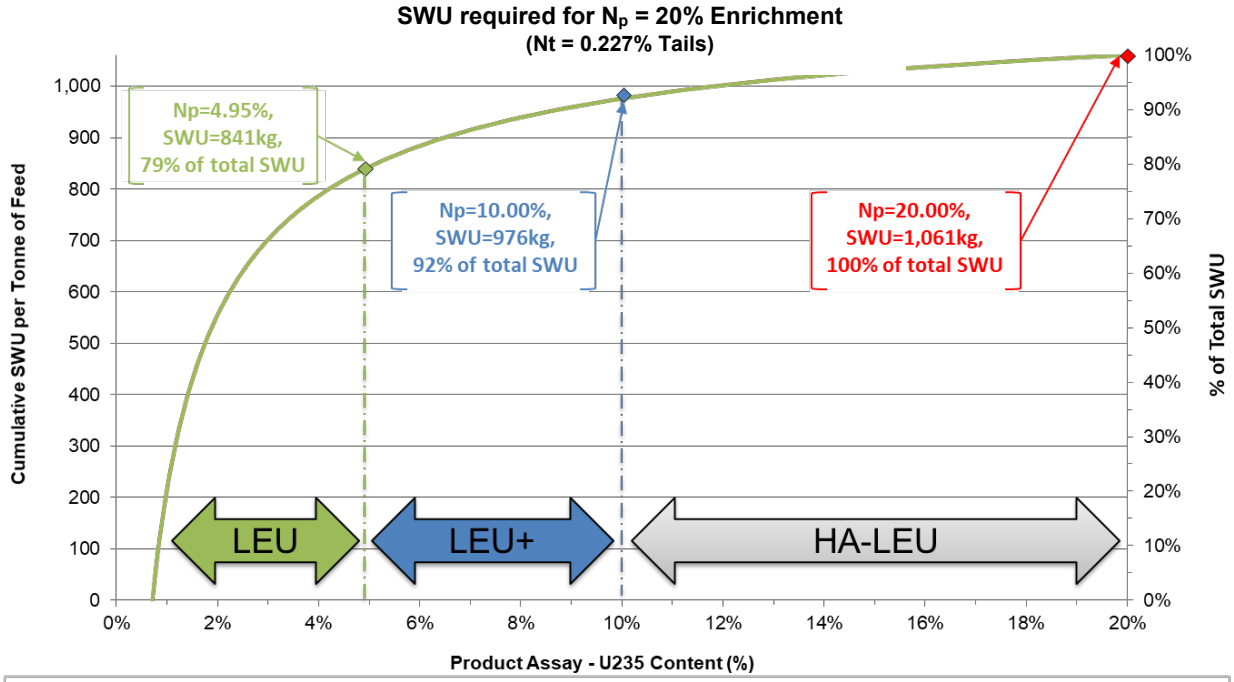

~92% of the separative work (SWU) required to enrich natural UF6 to 20% 235U, is consumed in the enrichment of LEU+ to 10% 235U.

HALEU Supply Chain Development

Question 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?

See response to Question 3 above.

Question 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.

Investment by DOE in the HALEU Availability Program will support environmental justice initiatives by promoting additional investment in communities that would benefit from such investment and from related economic growth and job creation. As DOE determines the appropriate structure for its HALEU Availability Program and community impact, it should also consider incentivizing domestic companies that

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have established community presence and are actively engaged in promoting equity within their workplace and communities.

The UUSA site in Eunice, New Mexico currently offers significant economic and job benefits to the local communities, including: i) direct employment of approximately 230 individuals and as well as approximately 100 long-term contractors; ii) support for local and wider regional initiatives, including sponsorships, donations, educational initiatives and student internship programs, as well as volunteer activities. Annually, UUSA provides $500,000 in sponsorships and donations to the community, and in 2021 47% of UUSA's new employees were hired from the local community.

The local communities in the area in which the UUSA site operates have diverse populations, include minority and lower-income households. In Lea County, New Mexico where the site is located, minority groups make up the majority of the county's population, and approximately 60% of the overall population is Hispanic. The site is also located in an area in which significant employment is focused on fossil fuel extraction. Additional clean energy investments by DOE through its HALEU Availability Program would provide substantial economic and employment benefits for the local communities, as well as offer opportunities for workers impacted by transitions in the energy sector, while also advancing clean energy and energy security goals.

To maximize investment in the local communities, economic support and jobs, Urenco USA Inc. would also be willing to consider, if asked by the U.S. Government or other commercial partners, to leverage its existing Category III production facility by hosting other company Category II HALEU production facilities, including deconversion facilities as well as facilities that may use other enrichment technologies in order to optimize the cost of HALEU production for advanced reactor consumers. Urenco USA Inc. would also be willing to consider an American Enrichment Campus concept to help build and operate other non-Urenco technologies at its UUSA facility, if the U.S. Government deems that another enrichment technology is better suited for HALEU production. The extent of optimization would be a function of the ability to leverage not only existing site infrastructure and land, but also regulatory, security, maintenance, operation functions and shared services.

Question 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.**

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Supply for HALEU to be used by advanced reactors can be described in three phases: i) U.S. Government supply; ii) U.S. Government supply coupled with an optimized commercial production; and iii) supply from multiple commercial production platforms in a competitive market. The three demand and supply phases do not need to align exactly in time because it should be possible to accelerate investment in production from an optimized commercial platform by leveraging existing enrichment infrastructure and by the U.S. Government acting as a "wholesale buyer" of HALEU by purchasing the output of the optimized commercial platform and reselling to advanced reactor developers and/or operators until there is a sufficient fuel supply to justify investment in multiple commercial production options.

All approaches by the U.S. Government to establish a HALEU Availability Program will be subject to the availability of appropriations. One approach to support the creation of a commercial market for HALEU would be for the government to act as a wholesale buyer of HALEU products for a finite time, purchasing and reselling HALEU in the form of UF_6 in order to guarantee fuel supply for new reactor developers, reassure potential advanced reactor customers that fuel will be available, and reduce risk for all market players. A consortium based approach involving the full user community, in partnership with DOE, to purchase HALEU materials and to develop a schedule for full cost recovery would be an effective mechanism. Such an approach could position U.S. companies to develop a robust HALEU fuel cycle and serve the growing community of users. Such public-private cooperation would: foster development of a domestic infrastructure supporting HALEU supply to already operating research and test reactors; provide suitable HALEU supply for testing and start-up of prototype fuels and reactors; and further support deployment of advanced technologies.[4]

Potential other approaches could include take-or-pay contracts, or cost sharing to reduce financial risk and accelerate development, either through sharing capital expenses with fuel suppliers to encourage HALEU facility development, or providing funding to reactor developers to promote long-term firm contracts for the purchase of HALEU. Companies operating within the nuclear fuel supply chain must make significant capital investments and long-term contracts would provide the greatest funding certainty. To the extent DOE pursues contracts or cost-sharing arrangements, such approaches should be competitively bid and equitably considered and evaluated, focusing on the most cost-effective approaches. A key impact of government cost-sharing capital expenses is to reduce the price of HALEU because an enricher would not need to make a return on the government's investment. A cost share would not obviate the need for long-term firm contracts for HALEU supplies between an enricher and consumers.

An additional approach would be for the U.S. Government to consider how it could potentially act as a guarantor of contracts between private parties as discussed in response to Question 4. Such a mechanism would give the confidence necessary to invest in the HALEU production capability in the amounts needed to meet the needs of civilian research reactors, medical isotope production, and advanced reactors.

[4] A precedent for the "wholesale buyer" model within the DOE Office of Science, which is DOE's National Isotope Development Center. This program supports the U.S. Department of Energy Isotope Program as the global leader in the production and distribution of radioactive and enriched stable isotopes that are deemed critical or are in short supply. *See* | NIDC: National Isotope Development Center (isotopes.gov).

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Question 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?

In its conceptual design work, Urenco has interfaced and consulted with many other industrial partners who have a specific interest in developing a commercial source of HALEU. One of the most significant issues identified which needs to be addressed in the development of a commercial fuel cycle for supply of 10% to 20% U-235 is the public transport of intermediate forms of enriched uranium. UF_6 is the chemical form of HALEU that would be produced at the UUSA site, but no commercially practical packaging exists for transporting HALEU in this form. No research reactors, test reactors or demonstration reactors identified to date require HALEU in this form.

The development of such packaging, however, is now underway and applications are currently pending with the NRC.[5] In its recent report to Congress, NRC stated that its staff have determined no near-term regulatory or policy updates are required for transportation plans and that all reviews of pending transportation packaging amendment requests will be completed by June 2022.[6] Assuming certified transport packages are available in the near term, this will support the timely development of a domestic HALEU capability.

Question 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?
(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?

Not applicable.

Question 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?

For enrichment facilities, co-locating the HALEU Category II facility with an existing Category III facility would both eliminate the need and cost of transporting uranium and leverage existing NRC quality assurance programs, security, infrastructure and human resources of the existing facility to minimize cost

[5] Packages designed for the transport of fissile nuclear materials on the public roads must meet rigorous performance standards. There are also additional requirements imposed on packaging HALEU materials in the form of UF_6. Industry experience shows that the process of designing, testing, licensing and manufacturing such packages is a multi-year process.

[6] See note 2 above, NRC report at p. 2.

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of the HALEU production facility. Co-locating the HALEU facility with an existing Category III facility would also significantly reduce the footprint of the HALEU facility because the feedstock for the HALEU facility would be generated at the Category III facility. The largest amount of separative work in producing HALEU is associated with enrichment up to 10% U-235. *See* Response to Question 7 above. At its UUSA site, the feedstock for the HALEU facility would be generated at its existing Category III facility significantly reducing those costs.

An additional advantage to co-location of the HALEU facility with an existing Category III facility is that the assembly and installation of the required centrifuges for the facility will be possible using existing infrastructure. A Centrifuge Assembly Building (CAB) is essential to assemble centrifuge components and must be available at the site because completed centrifuges cannot be transported without damage. The CAB is a large structure containing highly specialized equipment. The entire CAB, similar to a semiconductor manufacturing facility, must be kept extremely clean to avoid contamination of centrifuge components. Leveraging this existing infrastructure would further reduce capital investment for the assembly of the HALEU facility.

Co-locating a HALEU facility with an existing Category III facility would also facilitate more timely regulatory processes, including with regard to siting, environmental justice and other issues. As part of the initial licensing of the UUSA site, NRC conducted a full review and licensing process which included consideration of environmental justice issues. NRC evaluated these issues and prior to the granting of the license and construction of the facilities determined that the construction and operation of the site would not disproportionately adversely affect minority or lower-income communities. NRC further found that the site provides significant economic and employment benefits to the local communities in southeastern New Mexico.

As discussed above, co-location of conversion and/or conversion and fabrication facilities would also provide benefits by consolidating HALEU processing at fewer sites and avoiding the need to transport intermediate forms of HALEU on public highways. In addition to reducing the number of transportation steps and packaging requirements, it may also reduce the time and burden associated with new licensing reviews.

Question 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.

No additional comment.

Regulatory Issues

Question 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?**

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A facility for the enrichment of uranium between 10% and 19.75% U-235 falls under Category II physical protection requirements, and a HALEU enrichment capability at the UUSA site would require a license amendment to its existing materials license. A HALEU facility could be co-located within the existing enrichment site, providing several benefits, not only for infrastructure and personnel availability, but also from a commercial perspective. As discussed above, LEU and LEU+ can be used as feedstock for the HALEU facility, optimizing its output, while minimizing the footprint of the plant and size of the investment. Another advantage of operational integration of the two facilities is derived from the pre-existing investments in the infrastructure needed to assemble, test and install centrifuges.

Key regulatory requirements for a new HALEU facility include the understanding of what Additional Security Measures (ASMs) would be imposed on UUSA through an NRC order. To timely develop a domestic HALEU capability, it will also be imperative that enrichment, conversion, fabrication and transportation packages be licensed and developed on concurrent schedules. Otherwise there will be gaps in the fuel cycle and the industry will not be able to reap the benefits of advanced designs and Accident Tolerant Fuels.

Question 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).

The Energy Act of 2020 provides that the Department develop, in consultation with the NRC, criticality benchmark data to assist the Commission in licensing and regulating special nuclear material fabrication and enrichment facilities, and certification of transportation packages. LES has recently submitted a license amendment request for revision of its nuclear criticality safety analysis to include computer codes for criticality applications for future activities relating to higher assay fuel enrichments. This adds benchmark experiments to LES' previous validation, and LES anticipates no additional benchmark data would be required to support its future production of higher assay fuels.

Criticality experiments that can be used to benchmark analysis of dry UF_6 transportation packages for HALEU may be of benefit to assure certainty in the licensing process. Urenco USA Inc. supports DOE's efforts to develop criticality and/or benchmark data that may assist the Commission in licensing and regulating special nuclear material fabrication facilities and transportation packages.

Question 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?

For the HALEU required for such advanced reactors, an additional consideration relating to the HALEU lifecycle is that a HALEU facility does not produce any depleted uranium. Rather, due to its enrichment levels the depleted uranium stream from a HALEU cascade can be used to be re-enriched at the existing Category III facility or even as LEU in a light water reactor fuel cycle.

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Question 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?

As the U.S. seeks to cooperate internationally to deploy clean energy technologies, the U.S. Government should consider the potential for international cooperation and collaboration in HALEU fuel development. Ultimately, it is anticipated that the market for advanced reactors, including small modular and micro-reactors, will be a global market. Currently, to advance clean energy goals, other nations including Canada, the United Kingdom, European Union governments, Japan and other countries are actively supporting the development and deployment of advanced reactors through funding and licensing activities. To advance those efforts, the U.S. Government could consider including HALEU in discussions with these governments, including with respect to the design and development of HALEU facilities, consistent procedures and approaches, and potential opportunities to develop an international fuel bank or other mechanism to meet global needs. One near term opportunity could be to include HALEU as a topic for discussion in connection with the pending US-UK Strategic Energy Dialogue announced at the Glasgow Conference and for which there are meetings scheduled in the Spring 2022.

Financial Barriers

Question 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?

As discussed above, there are financial challenges associated with developing a sustainable commercial fuel supply chain for HALEU due to the business and regulatory uncertainties in the timing and demands of the commercial market for HALEU as advanced reactors are demonstrated and deployed commercially. As also discussed above, actions of the U.S. Government can help to mitigate that risk, including through long-term firm contracts, a potential fuel bank, cost sharing and other mechanisms. Please see responses to Questions 3, 4, 5, and 10 above.

Human Resources

Question 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 development and deployment of commercial scale HALEU production facilities, including for enrichment, requires a wide range of skill sets. An experienced and trained workforce is needed, including but not limited to individuals with experience and expertise in design, engineering, licensing, construction, operations, compliance, logistics, safety and emergency response, security, maintenance, finance and accounting, information technology, procurement, and human resources.

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The existing UUSA site was constructed and began initial operations in 2010, and subsequently expanded operations in a second and third phase which was completed in 2018. During each phase of construction there was a significant increase in the number of construction and related jobs in connection with the expansions completed in 2018, including workers primarily from local communities and other locations in New Mexico. This recent experience and skill sets developed in constructing facilities would be utilized in the development and construction of a commercial HALEU facility at the existing site.

- **Please describe the nature of any anticipated shortage in subject matter expertise and its potential impact.**

The UUSA site has approximately 230 employees, including highly skilled and experienced employees in all areas of its operations, as well as approximately 100 long-term contractors. Similar skills, experience and expertise required at the existing UUSA site would be required for the development and operation of a HALEU facility. While enrichment to HALEU presents specific demands on criticality assessments and engineering and training to develop experts in this fields, leveraging an existing site and workforce would help to facilitate the development of needed expertise.

Urenco USA Inc. recognizes the importance of continuing to educate and develop a skilled workforce, and strongly supports the Department's and industry efforts to continue to train and develop criticality and engineering experts. To facilitate education and development of its workforce, the UUSA site has management, technical, safety and other trainings. To promote opportunities for students in the local communities, UUSA also provides scholarships to local students every year, and conducts workshops for teachers and students to learn more about the nuclear industry. Each year 1,600 fifth-grade students in Lea County, New Mexico and Andrews County, Texas participate in UUSA's annual Richie Enrichment Science workshops.

Other

Question 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?

As DOE develops its HALEU Availability Program, it should consider the most realistic time frames for the deployment of advanced reactors, consistent with current experience, and should facilitate the timely licensing of HALEU fuel cycle facilities. Additionally, DOE should take into account foreign policy considerations, including trade issues and competition from Russian state-owned enterprises, and seek to reduce or eliminate dependence for HALEU on suppliers in foreign countries where supplies are less reliable and/or predictable, may be affected by trade restrictions or sanctions, or otherwise may not be stable sources of supply.

* * *

Urenco USA Inc. would be pleased to provide DOE with any additional information that may be useful. Urenco USA Inc. would also welcome site visits by DOE to explore opportunities to facilitate the

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development of a domestic HALEU supply for civilian domestic research, development, demonstration, and commercial use.

Please do not hesitate to contact me at (703) 682-5211 (office) or (571) 243-3778 (cell), or by email at mary.neumayr@urenco.com.

Sincerely,

Mary Neumayr

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