

Characterizing an Emerging Market for High-Assay, Low-Enriched Uranium Production

Summary for Policymakers – December 2023

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Ensuring a reliable and robust commercial supply of high-assay, low-enriched uranium (HALEU) fuel is critical to the successful commercialization and deployment of many advanced reactor designs. Commercial HALEU is currently only available from the Russian state-owned company TENEX, posing a significant commercial risk for advanced reactor projects that require HALEU. Catalyzing domestic commercial production of HALEU will reduce U.S. dependence on supply chains that are subject to international geopolitical and economic disruptions, enable the successful deployment of advanced nuclear energy as a clean energy solution, and create a reliable domestic source of advanced reactor fuel to support global export of U.S. nuclear energy technologies.

Despite stakeholder agreement that a domestic commercial HALEU market and fuel cycle is needed, and recent action by the U.S. Congress, the Department of Energy, and private companies to address the HALEU fuel cycle challenges, there has been limited public discussion on the market challenges of effectively incentivizing private investment in new HALEU production capacity. Specifically, while high-level estimated costs of HALEU production and funding requirements for a federal program to catalyze investment in new HALEU production capacity are adequate for program establishment, more detailed and robust characterization of costs and funding requirements is needed for program implementation.

NIA developed a highly technical report to fill this need by characterizing and quantifying HALEU production costs and analyzing two different types of HALEU availability programs. These analyses provide a common basis for discussion between advanced reactor companies, fuel cycle service providers, fuel end users, and policymakers on the programmatic needs to catalyze new domestic commercial production of HALEU.

NIA's new report includes detailed evaluations of program implementation options that reinforce on-going work by Congress to secure additional legislative authorizations and appropriations for domestic HALEU production. This summary for policymakers focuses on the report's high-level policy takeaways. The full report can be found [here](#).

Policy Takeaways from HALEU Production Cost Analysis

The HALEU production cost model provides qualitative and quantitative analysis of HALEU production costs and cost drivers. There are several key policy implications that are supported by the quantitative and qualitative evaluations performed in this report that can help decrease the costs associated with HALEU production and government support.

- 1. Calculated HALEU production cost for uranium enriched to 19.75% is \$23,725 / kgU for HALEU in an oxide form and \$25,725 for HALEU in a metallic form under baseline economic assumptions but could be higher.**

Approximately 65% of the HALEU production costs are driven by existing commercial low enriched uranium (LEU) fuel cycle activities (including uranium mining, uranium conversion, and LEU enrichment) subject to existing commodity costs and market dynamics. The remaining 35% of HALEU production costs are driven by new HALEU production activities (including HALEU enrichment and deconversion). These costs may vary based on the scale of HALEU production capacity and economic assumptions about facility operation. Longer and larger guaranteed contracts can lower both short-term and long-term production costs for new HALEU production facilities.

2. Leveraging existing commercial LEU as feedstock for HALEU production takes advantage of lower LEU enrichment costs and will reduce HALEU production costs, especially for near-term HALEU production.

The HALEU production cost model illustrates that more than six times more separation work is required to enrich uranium from natural uranium to 5% U-235 than to enrich uranium from 5% U-235 to 19.75% U-235 for each kilogram of HALEU produced. LEU enrichment will be cheaper than HALEU enrichment due to existing commercial markets, costs associated with new facility construction and operation, and regulatory requirement differences between production of LEU and HALEU materials. Use of lower-cost LEU enrichment services as part of the HALEU production process significantly reduces the overall cost of HALEU production. If HALEU enrichment facilities can be commercialized and deployed at scale (taking advantage of economies of scale of production and long-term amortization of capital costs), it is possible for long-term HALEU enrichment costs to decline and approach existing LEU enrichment costs.

3. Ensuring a robust commercial LEU market is key to minimizing HALEU production costs

The HALEU production cost model estimates that 65% of HALEU production costs under baseline conditions will be dependent on uranium commodity products and fuel cycle services that support existing LWRs. The market for LEU fuel is global and can fluctuate based on challenges and risks to supply and demand. Volatility and increases in LEU prices (such as those seen following the 2022 Russian invasion of Ukraine) will have a significant direct impact on HALEU prices. Ensuring a robust LEU market using commercial and policy solutions (preferably with U.S. or Western LEU production) is critical to maintaining low and predictable HALEU production costs.

4. Supporting investment in domestic HALEU and LEU production supply chains is critical to reducing uncertainty in HALEU production costs.

Investment in new HALEU production capacity is critical to reducing both the cost and cost uncertainties for HALEU production. Ensuring a robust LEU supply chain may also require additional investment in domestic LEU infrastructure. The costs associated with HALEU enrichment and deconversion activities will depend significantly on economies of scale for new commercial facilities, with large uncertainties based on commercial arrangements. These costs may be significant for commercial enrichment or deconversion facilities that are first-of-a-kind or have a limited production capacity (e.g., < 10 metric tons of uranium per year). Other supply chain activities (i.e., development of transportation infrastructure) without existing commercial customers would benefit from direct or indirect federal support to help ensure availability of these services and to minimize the potential effects on HALEU production costs.

Policy Takeaways from HALEU Program Evaluations

The HALEU program evaluations provide quantification of how different federal programs could catalyze private investment in a mature, sustainable, and domestic commercial HALEU fuel cycle.

The first program implementation option is a HALEU “material off-take agreement program”. The federal government would provide multi-year contracts to private companies to produce a fixed amount of HALEU annually (e.g., MTU/y) at a fixed price (\$/MTU). These contracts for commercial HALEU producers would create a reliable demand signal for private investment in new HALEU production capacity. The U.S. Department of Energy began implementing a HALEU material off-take program through the HALEU Availability Program with authorization in the Energy Act of 2020.

The second program implementation option is a HALEU “production services agreements program”. The federal government would provide multi-year contracts for HALEU production services (e.g., HALEU enrichment and deconversion) to create a reliable demand signal for commercial investment. For example, they could contract for HALEU enrichment services (e.g., SWU/year) at a fixed price (e.g., \$/SWU). The contracts for commercial HALEU production services would create a reliable demand signal for investment in new HALEU production capacity.

There are several key policy implications of the analyses of these two program implementation options that can help decrease the cost associated with catalyzing development of a mature commercial HALEU market in the United States.

1. Significant increases in total federal funding (in addition to the \$500 million in the Inflation Reduction Act) are necessary to catalyze private investment in commercial HALEU production.

The “HALEU material off-take agreement” would require total up-front appropriations of \$1.5 billion to \$2.9 billion for successful program operation if a “revolving fund” and “negotiated contract buy-outs” are used to support program operation.¹ If the program cannot use a revolving fund or negotiated buy-outs, then the total up-front appropriations need for the program would increase significantly to \$6.3 billion to \$7.2 billion.

The alternative “HALEU production services agreement” program would require total up-front appropriations of \$2 billion for successful program operation. This program may require additional subsequent appropriations (on the order of several hundred million dollars per year) to complete HALEU material production if commercial advanced reactor deployment is significantly reduced or delayed.

Additional Congressional appropriations could be required for either program implementation option if market conditions diverge significantly from the expected HALEU production costs or industry HALEU demand.

2. Federal funding must be guaranteed over a substantial period of time (10 years) to catalyze private capital investment in a sustainable domestic commercial HALEU market.

Guaranteed market demand at sufficient volume and pricing over a period of 10 years is required to create the market conditions necessary for private investment in new HALEU production infrastructure. If funding is not guaranteed or sustained over a sufficient period of time, it is unlikely that market conditions will support substantial private investment in new HALEU production capacity.

3. New HALEU program legislative authorizations are needed to most efficiently support HALEU market development and maturation.

Additional Congressional authorizations would help enable more effective HALEU program operation:

- New legislative authorization to enable use of a “revolving fund” and “negotiated contract buy-outs” for a HALEU material off-take agreement result in fewer up-front appropriations and limit taxpayer liabilities. New legislative authorization (such as those included in the *Nuclear Fuel Security Act*²) would enable use of a revolving fund as part of HALEU material off-take agreement.
- New legislative authorizations would be required to enable use of “HALEU production services agreement” program to catalyze private investment in new HALEU production capacity. This program model is not currently authorized to support HALEU production in the Energy Act of 2020.

Additional legislative authorizations for the HALEU Availability Program would increase the likelihood of program success and reduce the total up-front appropriations requirements, thus enabling the faster development and implementation of a sustainable and successful HALEU development program.

¹ The HALEU material off-take agreement program appropriations requirements are consistent with the HALEU portion of the combined LEU-HALEU program appropriations using a revolving fund described in NIA’s June 2023 paper ["Additional Flexible Funding is Needed to Break Dependence on Russian Nuclear Fuel"](#)

² [H.R.1086: Nuclear Fuel Security Act](#)