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How Much Does It Cost to Develop New Nuclear Fuel Capacity?

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Takeaways

- Total program costs to develop US fuel enrichment capacity for high assay low-enriched uranium (HALEU) are $4-5 billion including CAPEX, offtake, conversion, and deconversion support.

- Upfront appropriations on the order of $2-3.5 billion are needed to secure multiyear offtake contracts with enrichers and provide the firm demand signal necessary to unlock industry investments in new capacity.
- The upfront costs of the fuel program could be reduced by establishing a revolving fund, however robust funding is needed in the near-term to secure offtake commitments.
- The primary driver for increasing LEU production will be market conditions rather than federal assistance. There is expandable domestic capacity to produce LEU that may be able to fill additional market demand in the next 5 years.

Developing New Domestic Enrichment Capacity

What do these costs mean?

- There's been a lot of conflation in estimated high assay, low-enriched uranium (HALEU) program costs between the capital expenditure (CAPEX) cost necessary to construct the infrastructure and secure equipment for the enrichment process and the "offtake" cost incurred in providing industry with guaranteed annual market commitments necessary to ensure that investment in new capacity is economically viable. Beyond CAPEX, enrichers will incur additional costs to staff, operate, and maintain the new facility, as well as product specific enrichment costs. To secure these costs, the USG will take the role of the initial customer and provide the demand signal through guaranteed offtake contracts as part of a HALEU procurement. The following sections breakdown the projected total program cost for standing up HALEU production.
- **Total program costs are not the final net costs:** In executing the DOE's projected program, the department would take ownership of 150 MTU of HALEU. Total program costs do not reflect the revenue generated during the resale of 150 MTU to industry (the HALEU Consortium) at negotiated prices. The net costs for the HALEU program will therefore be determined by subtracting the resale value of 150 MTU HALEU from the total program costs. A revolving fund approach could use the future revenues from the HALEU resales to pay for out year deliveries, thereby resulting in a lower upfront program cost. However, substantial funding will still be needed to secure offtake commitments and any future fluctuations in outyear demand could jeopardize the program's viability.

How much does new domestic HALEU capacity cost?

- **Enrichers have publicly estimated $300-$500M in capital expenditure for a new US HALEU facility** that could be built and operated in 4-5 years. This is solely the CAPEX for the infrastructure and licensing costs and does not include the cost of operating the facility over the multi-year performance period needed to meet the Department of Energy's draft RFP. Some enrichers have stated that they would not need USG assistance to cover CAPEX costs, others would require some level of USG support for CAPEX costs, either in forward payment, cost-share grants, or a loan guarantee.

- **It is unclear how many reactors this would service, but TerraPower and X-energy have projected their combined annual operational needs as ~15 MTU annually.** [1] The combined startup requirements for TerraPower's Natrium and X-energy's Xe-100 plants will be 21 MTU of HALEU divided over a three-year period. [2] DOE has projected a national need for more than 40 MTU of HALEU before the end of the decade. [3]

How much $ in market commitments are needed to make new capacity viable?

- **Enrichers have publicly noted that the minimum viable initial enrichment facility capacity is ~10 MTU HALEU/year**. This means that DOE offtake commitments will need to guarantee at least 10 MTU/yr at projected market cost to unlock industry investment in new US enrichment capacity. In order to provide a sufficient demand signal and enable a scalable market supply of HALEU, DOE originally aimed to procure 25MTU/yr for 6 years. [4]

Here's where it gets tricky—

- **The most recent published price for HALEU was $25,600 per kgU.** There aren't many published price estimates for HALEU costs. This is partially due to the nascent market for HALEU, but also to the suppression of uranium market data by the only commercial supplier of HALEU in the world—Russia. The most recent estimate is a 2019 Euratom Supply Agency report which set a price target of €20,000 per kgU. [5] Adjusted for inflation and today's exchange rates, that's ~25,600 per kgU.

- **The $25,600 per kgU is an outdated figure.** The price of LEU, the feed material needed for HALEU production, has more than doubled since the report was released. In May 2019, LEU cost $1100/kgU compared to ~$2700/kgU today. These increased feedstock costs mean that a kgU of HALEU would be roughly $7,000 more costly to produce today than it would have been when the published price was developed. [6]

- **At-minimum, $3.84B will be needed in DOE backed offtake commitments to procure 150 MTU.** Twenty-five MTU/yr x 6 years = 150 MTU, or 150,000 kgU.

And the Total Program Cost Is...

- **$3.9B - $4.4 billion conservatively.** Adjusting for current LEU prices, variations in enrichment process, and (likely) future shocks to global LEU prices due to Russia sanctions/manipulation could impact the market costs of LEU feedstock and increase the necessary total program costs.

Total Costs to Develop Domestic HALEU Capacity

CAPEX for facility infrastructure and licensing	$300-$500M
Market commitments/guaranteed offtake	$3.8B+
Domestic conversion and deconversion capacity	$100M
Total	**$3.9 - 4.4B**

Source: Author's calculations.

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Okay, so what about LEU?

- **NEI estimated that US plants use ~2000 MTU of LEU annually.** [7] The only domestic enrichment facility currently operating in the US is the Urenco USA plant in Eunice, New Mexico. The majority of LEU used by US nuclear power plants is purchased from foreign entities.

- **The National Enrichment Facility in New Mexico produces ~4,600 tSWU/yr**; this represents roughly a third of US annual demand. [8] Maximum capacity for the plant is estimated to be 4900 tSWU/yr. [9] In 2015, NRC approved a license amendment to increase capacity to 10 million SWU/yr. This expansion, if completed, could supply about 60% of US demand in the 2020s. [10]

- Support could be given to expand the development of domestic LEU capacity, however, as LEU markets are mature, the primary driver for capacity expansion will be the demand signal of excluding Russian uranium from the US and/or Western market. Such a signal could be sufficient assurance for industry to make the necessary investments in new capacity without a USG role in the offtake process.

Conclusion

Until DOE finalizes the draft HALEU RFP and begins the process of soliciting proposals for the HALEU procurement, there will remain questions about the total advanced nuclear fuel availability program costs. As appropriations bill markups begin to take-off, Congress needs to act to provide funding at the levels needed to support these efforts. Regardless of whether the fuel program is funded in total or through establishment of a revolving fund, upfront appropriations on the order of $2-3.5 billion will be needed to secure multiyear offtake contracts with enrichers and provide the firm demand signal necessary to unlock industry investments in CAPEX and labor. [11]

These investments, while significant, are necessary to unleash the market potential of many US advanced reactors and provide the US with a sharp competitive edge to counter the Russian and Chinese nuclear industries. If the US fails to secure the supply chain for HALEU fuel, we'll defer US global leadership to foreign competitors all while squandering the billions in clean energy investment passed by the Biden administration.

TOPICS

NUCLEAR 200

ENDNOTES

1. TerraPower and X-energy have projected their combined needs based on anticipated deployments through 2036, in the range of 8-58 MTU through 2030; and 75-137 MTU through 2034. TerraPower and X-energy. "Joint RFI Response FINAL Fully Executed". *Regulations.gov.* 14 Feb 2022, https://www.regulations.gov/comment/DOE-HQ-2022-0004-0023. Accessed 13 June 2023.

2. TerraPower and X-energy. "Joint RFI Response FINAL Fully Executed". Regulations.gov. 14 Feb 2022, https://www.regulations.gov/comment/DOE-HQ-2022-0004-0023. Accessed 13 June 2023.

3. "Haleu Fuel Availability Delays Natrium Reactor Project." *World Nuclear News*, 15 Dec. 2022, world-nuclear-news.org/Articles/HALEU-fuel-availability-delays-Natrium-reactor-pro. Accessed 12 June 2023.

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5. "Securing the European Supply of 19.75% enriched Uranium Fuel". *Euratom Supply Agency.* Page 13. May 2019, https://euratom-supply.ec.europa.eu/system/files/2021-06/ESA_HALEU_report_2019.pdf. Accessed 12 June 2023.

6. Estimated at a conversion rate of 4.5 kgU of LEU used to make 1 kgU of HALEU, based on SME input.

7. "Updated Need for High Assay Low-Enriched Uranium". *Nuclear Energy Institute.* 20 Dec. 2021, *https://www.nei.org/CorporateSite/media/filefolder/resources/letters-filings-comments/NEI-Letter-for-Secretary-Granholm_HALEU-2021.pdf.* Accessed 11 June 2023.

8. "Global Operations - UUSA". *Urenco USA,* https://www.urenco.com/global-operations/uusa

9. "USA Nuclear Fuel Cycle". *World Nuclear News,* "https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-fuel-cycle.aspx. Accessed 13 June 2023.

10. "USA Nuclear Fuel Cycle". *World Nuclear News,* "https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-fuel-cycle.aspx. Accessed 13 June 2023.

11. Calculation based solely on the additional appropriations needed to fund multi-year offtake commitments at current LEU prices. Upfront funding needs would increase slightly if USG support were provided for enricher CAPEX costs.