THIRD WAY

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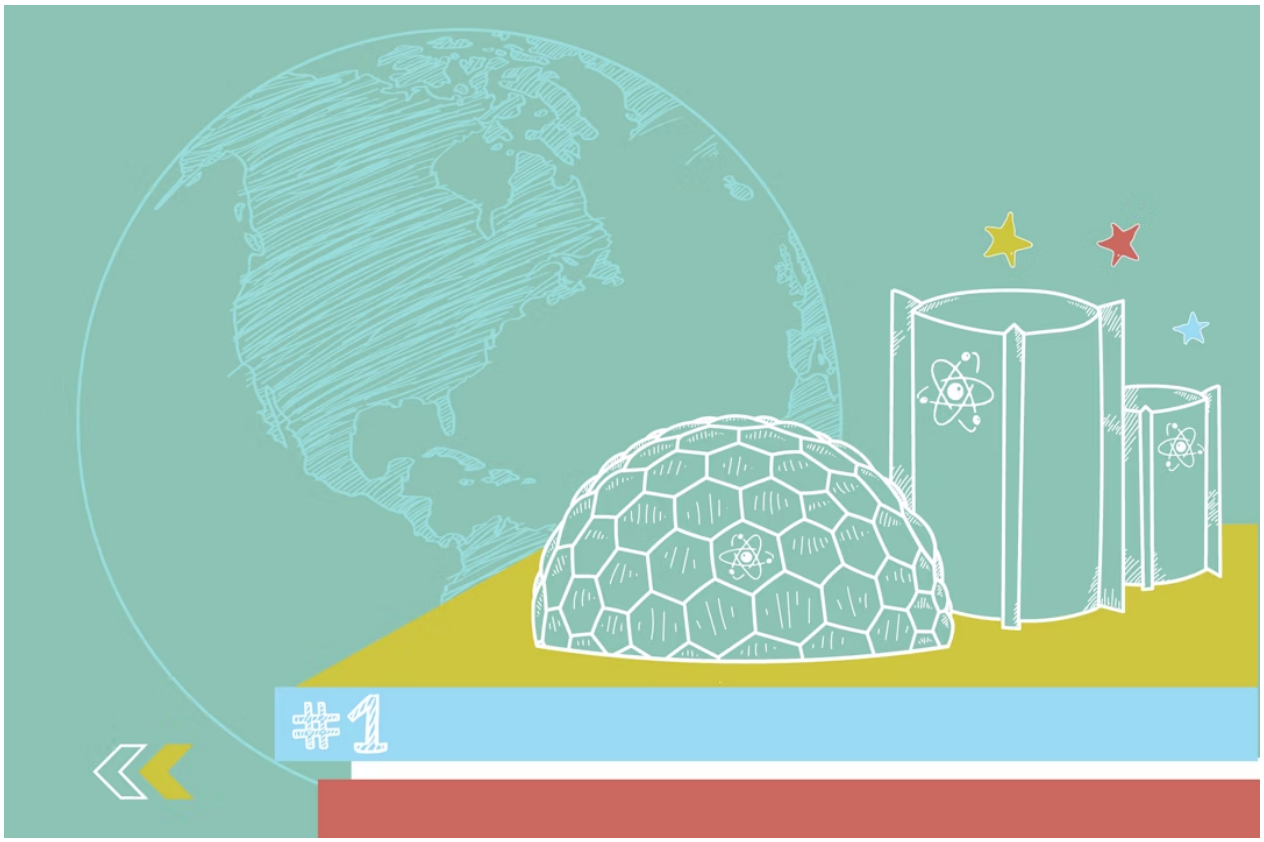
Advanced Nuclear Reactors: Policies to Help America Lead



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Takeaways

- US leadership and presence in the global nuclear energy market not only has commercial ramifications but will be immensely consequential for long-term US foreign policy, climate, geopolitical, energy security, and national security objectives and interests.
- US industry holds an advantage among international competitors in Raw Materials and Original Equipment Manufacturing (OEM) segments of the SMR value chain worth $180B+ in market value.
- Large scale federal investments from the Bipartisan Infrastructure Law and the Inflation Reduction Act are leading to the growth of OEM capacity and development of new intellectual property through the Advanced Reactor Demonstration Program (ARDP).
- Policies to support the development of front-end fuel cycle capabilities and the advancement of new reactor licensing will be critical to the long-term global competitiveness of US advanced reactors.
- Continued public and private investments in advanced construction and project implementation are needed to open opportunities for US industry in the $185B+ Engineering, Procurement, and Construction (EPC) segment of the SMR value chain.
- International cooperation between allies on other segments of the value chain could open significant opportunities for US industry to compete in potential and emerging markets.

The US Must Compete in the Growing Market for Nuclear Energy

Global demand for clean firm power and heat is rapidly growing—driven not only by urgency for climate action, but also as countries prioritize energy security and seek alternatives to Russian energy sources. Advanced small modular reactors (SMRs) [1] are uniquely suited to meet this

growing demand, given their potential scalability and flexibility in use cases. Advanced reactor technologies were originally conceived through research done at US national laboratories, providing US developers unique access to data and resources from this research.

In late 2022, Boston Consulting Group (BCG) released a groundbreaking report commissioned by Third Way and Breakthrough Energy finding that strategic investments in six key clean energy technologies could yield massive and lasting benefits for the US economy. This study identified the growing value chain for advanced nuclear reactors and highlighted major opportunities to expand the US' competitive edge for new nuclear technology. BCG's assessment of the global market for advanced nuclear SMRs is largely consistent with the results of research done by Third Way and Carbon Free Europe on future projections for this market. BCG's analysis identified two value chain segments where US industry has a competitive advantage: raw materials and original equipment manufacturing (OEM). Within the study, BCG recognizes both the serviceable addressable market (SAM), or the current total potential market for a technology across value chains, and the serviceable obtainable market (SOM), the share of the SAM that US companies are currently poised to compete for.

The US has been able to establish an early advantage in advanced reactors due to its existing regulatory and technical leadership among industry and government. These advancements have been bolstered by the significant investments in the Infrastructure Investment and Jobs Act (IIJA) and Inflation Reduction Act (IRA). This assessment will emphasize policies to make these advantages more durable and promote additional areas within these value chain segments where the US might be able to build a greater advantage. In doing so, the US could expand the SOM and open other opportunities within the greater value chain for advanced nuclear reactors.

> *Nuclear has to be part of the array of clean energy technologies, zero-carbon emitting baseload power. And so there is money both in the Bipartisan Infrastructure Law and as well as in the Inflation Reduction Act to incentivize the development.*
> *- Energy Secretary Jennifer Granholm on CNN's State of the Union.*

It is important to note the context in which such policies would be implemented. Third Way's most recent 2022 update to its global market for advanced nuclear map highlights the emergence of real demand in advanced SMRs around the world, especially as countries increasingly value energy security in the wake of Russia's invasion of Ukraine. Simultaneously, other international players are rapidly forging ahead with their own advanced SMR development programs and eroding the US

competitive edge in advanced nuclear. It is vital that the US seize upon its advantages in the key value chain segments, not only considering the commercial opportunities in advanced SMRs, but also the broader implications that this sector has for American geopolitical and national security interests.

State of the Competition

As shown in Third Way's 2022 advanced nuclear map below, there is a significant number of advanced nuclear projects throughout the world, and this number is only growing. Thus, we can expect intensifying competition over international advanced reactor markets in the upcoming decades.

Policy Recommendations

Technology-Wide

Integrated civil nuclear export strategy: Previous administrations appointed a nuclear energy director within the National Security Council (NSC), and the International Nuclear Energy Act of 2022 included provisions to establish an international nuclear energy policy office within the Executive Office of the President (EOP). Establishing an interagency coordinating function will be essential in view of the state of competition in the global nuclear market. Commercial deals for civil nuclear exports carry significant geopolitical implications as they require governments to build decades-long diplomatic relationships. Russia and China recognize this political value and support their state-owned enterprises with robust bilateral deals that include financing, fuel cycle management, and operations. Such agreement terms greatly lower barriers to entry and incentivize long-term partnerships with these foreign competitors. Considering the cutthroat nature of competition for these markets, the federal government has vital roles to play in supporting US industry in civil nuclear export bids and close interagency coordination will be crucial to achieving success. Mechanisms to better coordinate programs of relevance to international civil nuclear cooperation and exports at the various federal agencies will be critical to compete with Russian and Chinese state-owned enterprises more effectively. Moreover, a formal coordinating position or office at the White House can help identify and address potential bottlenecks in export licensing processes as broader efforts to streamline and rationalize the civil nuclear export control regime move forward. Ultimately, high-level coordination can kickstart progress towards support for more integrated civil nuclear export packages, including financing arrangements involving all available federal tools (EXIM, USTDA, DFC) and comprehensive fuel cycle services that cover assured fuel supplies to back-end management solutions.

Advance engagement and capacity building: It is essential that we bolster our capacity to proactively engage with potential international markets and assist interested countries in the

development of frameworks and institutions necessary to deploy and operate advanced SMRs. For example, in 2021, the US Department of State established the FIRST (Foundational Infrastructure for Responsible Use of SMR Technology) program to assist aspiring countries with capacity building so that they can establish new civil nuclear programs with the highest international standards for nuclear safety, security, and nonproliferation. Increased support for FIRST would complement initiatives in other agencies and issue areas—for instance, modest increases in funding to the US Nuclear Regulatory Commission's (NRC) Office of International Programs could significantly enhance the agency's bandwidth to engage with international counterparts and entities in sharing lessons learned and best practices in regulating advanced reactor technologies. Furthermore, the previously introduced INEA bill included $50M for grants to finance capacity building in potential markets. Increased resources for international capacity building activities will help facilitate the execution of bilateral civil nuclear cooperation, or 123 agreements, paving formal access to new markets in rapidly growing regions throughout the world. An expanded US global presence—such as increasing the number of State Department clean energy and DOE civil nuclear attaches stationed overseas—will also further catalyze the formation of the necessary diplomatic instruments to enable US nuclear energy exports in the future.

Regulatory modernization: Current licensing processes at the NRC are built around the experiences and data from licensing large conventional nuclear power plants. Congress passed the Nuclear Energy Innovation and Modernization Act (NEIMA) which mandated the NRC to establish a new technology-inclusive licensing framework for advanced reactors, though the NRC is still addressing this challenge. Congress should remain closely engaged in the work of the NRC by requesting a report or set of regular hearings to maintain expectations on the timeline and quality of the final rule. The NRC should continue in its efforts to build and develop its capacity to review advanced reactor technologies more effectively and efficiently. If necessary, the NRC should request additional funding for Advanced Reactor Regulatory Infrastructure Activities to support this work.

Regulatory harmonization: The NRC must also engage in regulatory harmonization and information sharing agreements with foreign regulatory bodies, such as the Memorandum of Cooperation it signed with the Canadian Nuclear Safety Commission (CNSC) in 2019. The NRC should build capacity to, ideally in a coordinated initiative with State Department and other federal agencies, actively engage nascent regulatory regimes where the NRC has pre-existing bilateral relationships to build consistent licensing standards for SMRs and socialize high-quality regulatory frameworks for civil nuclear programs. This knowledge exchange can be achieved through immersive training programs for foreign regulatory staff to learn directly from seasoned US regulators. NRC should also explore retaining senior staff, and in some cases contracting recently retired staff, to participate in short term overseas details to help advise new regulators as they build capacity. Socializing advanced reactor licensing standards that are based on US technology will reduce regulatory uncertainty for US developers in new markets and add durability to the US

competitive advantage. Additionally, establishing high-quality regulatory standards globally would raise the barriers to entry into international markets for foreign competitors.

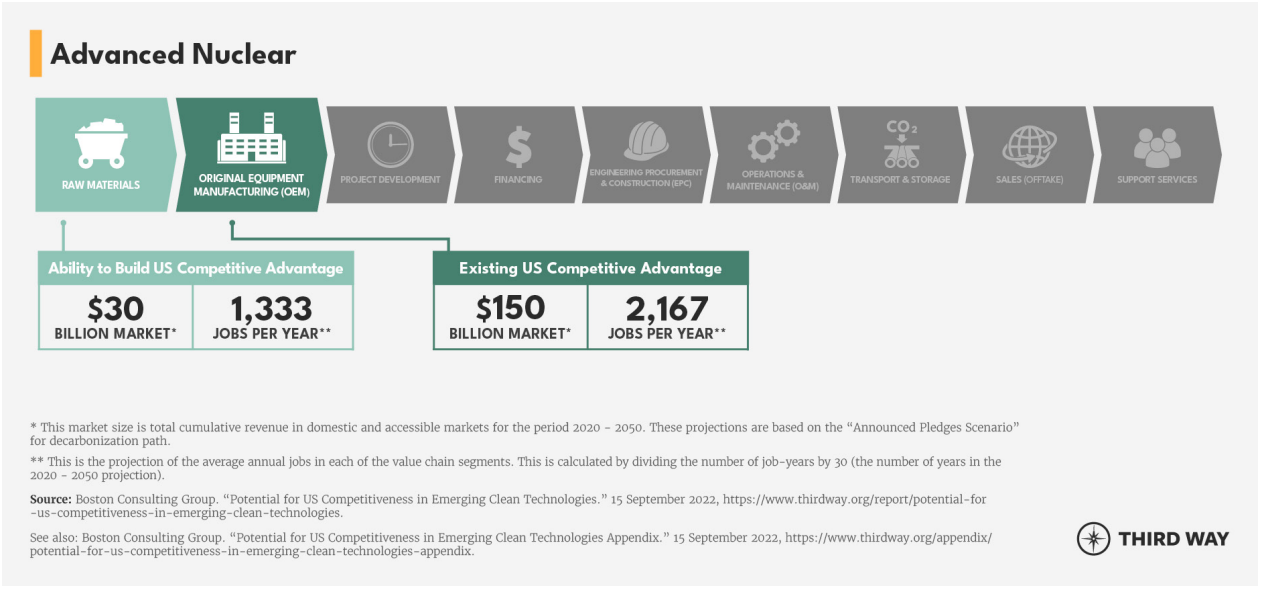
Federal procurement of SMRs: The US federal government should leverage its massive procurement power to kickstart the development of a domestic supply chain and workforce supporting advanced reactor deployment. For example, there has been significant interest by the US Department of Defense to deploy SMRs and microreactors to supply clean, resilient, and reliable power to domestic military bases and installations. This includes a 2021 announcement to site a microreactor pilot at Eielson Air Force Base in Alaska. Federal commitments to purchase a number of SMRs would send a significant demand signal that would further spur the development of the fuel cycle for advanced reactors, licensing of new SMR designs, and private investment in US reactor vendors.

Emerging Innovation Technology Tax credits: The Inflation Reduction Act (IRA) included a technology neutral production tax credit (PTC) and investment tax credit (ITC) for which SMRs would be eligible. These mechanisms are a great step to enable investment and reduce costs of large capital projects. Other proposals, such as the Energy Sector Innovation Credit (ESIC) that was proposed by Senators Sheldon Whitehouse and Mike Crapo would improve upon this concept by providing a flexible credit that incentivizes emerging technology. ESIC would allow up to a 40 percent ITC or 60 percent PTC for "low market penetration technologies." It would also phase out credits as technologies mature, thereby allowing new technologies time to "ramp up" and compete in the market on their own.

USG Investments Toward International Nuclear Energy Cooperation

At the 2022 G7 Leaders' Summit in Schloss Elmau, President Biden and world leaders formally launched the Partnership for Global Infrastructure and Investment (PGII) with the aim to mobilize $600 billion by 2027 in global infrastructure investments. The Administration announced that the US aims to mobilize $200B for PGII over the next 5 years through grants, federal financing, and leveraging private sector investments.

As part of this partnership, the US Government and NuScale Power, a US small modular reactor firm, will provide $14M to support the Front-End Engineering and Design (FEED) study for Romania's deployment of a first-of-its-kind small modular reactor (SMR) plant. According to the White House, "This investment is meant to mobilize a multi-billion-dollar effort and showcase US ingenuity in the advanced nuclear sector, accelerate the clean energy transition, create thousands of jobs, and strengthen European energy security while upholding the highest standards for nuclear safety, security, and nonproliferation."



* This market size is total cumulative revenue in domestic and accessible markets for the period 2020 - 2050. These projections are based on the "Announced Pledges Scenario" for decarbonization path.

** This is the projection of the average annual jobs in each of the value chain segments. This is calculated by dividing the number of job-years by 30 (the number of years in the 2020 - 2050 projection).

Source: Boston Consulting Group. "Potential for US Competitiveness in Emerging Clean Technologies." 15 September 2022, https://www.thirdway.org/report/potential-for-us-competitiveness-in-emerging-clean-technologies.

See also: Boston Consulting Group. "Potential for US Competitiveness in Emerging Clean Technologies Appendix." 15 September 2022, https://www.thirdway.org/appendix/potential-for-us-competitiveness-in-emerging-clean-technologies-appendix.

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Value Chain Segment: Raw Materials

Robustly fund and rapidly implement the HALEU Availability Program: Fuel supply is a critical near-term bottleneck for advanced nuclear that has elicited attention from policymakers. Many of the advanced reactor concepts closest to deployment will require high-assay low-enriched uranium (HALEU) fuel, for which no commercial market currently exists outside of Russia. In recognition of this critical supply chain gap, the Energy Act of 2020 established the DOE HALEU Availability Program to help fund the build-out of domestic fuel enrichment capabilities. Current DOE plans on the implementation of this program involve procuring significant quantities of HALEU and then reselling the HALEU to US developers at a fixed cost, thereby sending a market signal to incentivize US enrichers to make the necessary investments in HALEU infrastructure. The IRA provided $700M in funding for the HALEU program, of which $500 million is dedicated to supporting new production. DOE presently proposes to purchase 150 metric tons of HALEU over several years at an estimated total cost of approximately $3B. [2] Therefore, additional resources are necessary for the program in order to fund a competitive, multi-award request-for-proposals (RFP). DOE has started the process of seeking industry input on this award and aims to formally release a solicitation soon. Standing this program up as soon as possible should be a chief priority for the Department.

Coordinate with international allies to reduce Russian influence: Russia holds a significant proportion of global market share in both uranium conversion and enrichment, and international coordination will be required in order to alleviate our collective reliance on Russian uranium fuels in the long term. This fundamentally begins with rapidly expanding non-Russian global fuel production capacity. Once sufficient progress has been made towards investment in and build-out of both LEU and HALEU capacity outside of Russia, clear communication and coordination among the US and its allies will be absolutely vital to prevent re-entry of Russian suppliers and ensure durable market share for Western fuel producers. A controlled and strategic approach that harmonizes with the actions of our international partners will be necessary to both addressing long-term dependence on Russian supply and avoiding severe short-term disruptions.

RD&D: The US was once the dominant global supplier of uranium enrichment services until more efficient enrichment technologies emerged and enabled foreign vendors to gradually seize the global enrichment market. Public investments in early-stage, potentially disruptive technologies that are suitable for future commercial deployment can help secure a durable competitive advantage in raw materials. Sustained funding for RD&D programs, such as the DOE's Crosscutting Technology Development, Fuel Cycle R&D, and ARPA-E, will help US industry maintain its technological edge in these key markets.

Value Chain Segment: Original Equipment Manufacturers (OEM)

Provide manufacturing incentives for domestic suppliers: The IRA provides discretion to the Secretary of Energy to identify technology and projects "designed to reduce greenhouse gas emissions" eligible for the 48C credit. Clarifying through IRS rulemaking, and/or other agency guidance, that the Secretary recognizes nuclear energy technology and its components as eligible technologies under section C of the 48C tax credits, could be a major catalyst for revitalizing domestic civil nuclear suppliers. Providing manufacturing credits for the supply chain of advanced nuclear facilities, reactor components, fuel types, and integral energy storage technology would enable more domestic suppliers to compete for request-for-proposals and further build the domestic supply chain.

Domestic content requirements linked to deployment incentives: The IRA's industry provisions include some conditions that certain industrial products are sourced domestically. Such incentives for developers to source as many discrete parts and materials as possible from domestic fabricators would help spur supporting industries and build domestic expertise in nuclear component fabrication. A larger pool of domestic suppliers would also help reduce costs for reactor parts and make technologies more affordable. In the future, additional sourcing requirements for critical minerals, such as natural and synthetic graphite, could be added to tax incentives such as the PTC and ITC or as conditions for future federal loan programs and cost-shares.

Revise fee-based activity structure at NRC to reduce licensing cost burden on advanced nuclear developers: Current fee-recovery structure at the NRC requires licensees to fully cover the costs of application reviews and staff time. These costs can soar into the tens of millions of dollars for a single design. Congress should explore revisions to the NRC's fee structure for advanced reactors that could use a tiered/milestone fee structure which establishes lower fees in the early stages of the application process and higher fees in the later stages. This type of structure would flatten fee expectations across the board and would not prohibitively penalize applicants whose applications become stalled or rejected in early stages. Additionally, Congress should explore changes that would allow applicants to defer payment of fees for up to a certain number of years after a plant becomes operational. Such deferments would allow greater flexibility for new projects and further reduce barriers to entry for smaller reactor developers that may not be fully capitalized. These changes could result in greater IP development and more reactor options for potential markets.

> *"The opportunities for advanced nuclear technology will be critical if we're going to meet our climate goals."*

> *- EPA Administrator Michael Regan at a Press Conference in Japan at a series of meetings on furthering US-Japan cooperation on climate action.*

The Impact of US Leadership in Advanced SMRs

SMRs present one of the most open-ended market opportunities. The ultimate size of the market will depend on several factors related to securing the supply chain for raw materials, early engagement in potential markets, and the provision of financing pathways for foreign civil nuclear projects. The US Serviceable Addressable Market (SAM) for advanced nuclear SMRs is expected to range from 150 - 160 GW of total installed capacity under APS by 2050, up from <1 GW today. This growth will largely be led by European markets, with several Central European countries expressing significant early interest in SMR technology. As BCG notes, the market values and export potential in the study should be viewed as a "lower-bound estimate with significant upside potential." The flexibility, scalability, and lower capital costs of SMRs make them a great option for Southeast Asia and longer-term emerging markets. There may also be sizable market opportunities outside of the scope of the BCG study in the "offtake" value chain segment due to the non-electric applications of nuclear power.

Durable advantage in the raw material and OEM value segments will be driven by technical leadership, IP & innovation, and demand & supply side policies. A stable US advantage in the uranium fuel cycle and in advanced reactor fabrication would build domestic market maturity and technical experience that enhances the durability of these advantages while promoting domestic industries. Additionally, nuclear power plants have been shown to provide the highest wages in the civilian power sector. Coupled with a modernized regulatory environment and positive domestic market conditions, there is the prospect of significant job growth in the nuclear energy sector—in time to transition workers from shuttering fossil fuel facilities.

US nuclear developers have the competitive advantage to lead in international new nuclear markets largely due to bipartisan support for nuclear R&D and sustained USG investment in nuclear infrastructure. Policies to continue these investments and grow new R&D programs could further innovation and may unlock access to greater market value in the EPC value chain segment. DOE announced the Advanced Construction Technology (ACT) initiative with $5.8 million in funding to develop three construction technologies that could collectively reduce the cost of new nuclear builds by more than 10 percent. With continued public-private partnerships in R&D, US SMRs could

overcome the legacy challenges of GW-scale nuclear projects to provide greater market maturity and lower plant costs for EPC than conventional nuclear technology.

Beyond the economic benefits, smart and coordinated policies to support US development and exports of advanced SMRs would strengthen US global leadership in nuclear energy. This leadership has immense consequences for US geopolitical and national security objectives. Civil nuclear export deals cement long-term diplomatic relationships with key international partners, while simultaneously denying Russia and China opportunities to establish footholds for extending their geopolitical influence. Critically, nuclear energy is a major solution for our allies to strengthen energy security, thereby reducing their vulnerability to dependence on fossil fuel imports from hostile, authoritarian states. Moreover, America's presence in overseas nuclear markets directly impacts our ability to shape global norms and practices in nuclear safety, security, and nonproliferation. Within the raw materials value chain, our ability to provide reliable and competitively priced reactor fuels will disincentivize other countries from developing sensitive fuel cycle capabilities to support their civilian programs. This ability will not only advance American competitiveness, but also core US nuclear security and nonproliferation interests. Looking at the larger picture, it is abundantly clear that the stakes are not merely commercial when it comes to American leadership in this technology sector.

ENDNOTES

1. Many definitions of "Small Modular Reactors" have been used in publication. Additionally, the term "advanced nuclear" may be used to refer to technologies beyond SMRs, specifically. The BCG study defines SMRs as both light-water reactor (LWR) and non-LWR technologies with up to 400MWe capacity per system configuration and the ability for the reactor to be mass-produced in a factory setting.

2. DOE's Sources Sought Notice indicated that the department intends to purchase 25 MTU HALEU annually through 2032. Based on a likely production start year of 2027, 6 years of production at 25 MTU per year would result in a total procurement of 150 MTU. A 2019 report from the Euratom Supply Agency set a price target of €20 million/MTU HALEU resulting in a roughly $3 billion target price for HALEU. However, given inflation and supply chain constraints, current estimates for HALEU prices are limited and estimates for uranium feed materials are likely to vary.