DOE grapples with its future uranium supply

Proliferation concerns factor into the decision on whether new domestic production capability is needed.

CENTRUS ENERGY

A CASCADE OF AC100 CENTRIFUGES was operated for three years in a technology demonstration at a Centrus Energy facility in Piketon, Ohio.

The US Department of Energy is inching toward constructing a multibillion-dollar enrichment plant for nuclear weapons and other defense purposes. The most urgent concern, agency officials say, is for a continued supply of low-enriched uranium (LEU)—which contains about 4% of the fissionable ^{235}U isotope—for use in producing tritium for nuclear weapons. Longer term, there will be a need for new highly enriched uranium (HEU) to fuel the nuclear reactors that propel submarines and aircraft carriers.

"We do not have the capability today to meet our needs for fuel for [naval] reactors, nor for producing the tritium we need in our stockpile," former DOE secretary Ernest Moniz told an audience at the Center for Strategic and International Studies in Washington, DC, on 11 January. "We are living off of stockpiles that are sitting in the closet right now. . . . The clock is ticking."

"We are pursuing a domestic enrichment capability. It is a high priority for the department," said Art Atkins, associate deputy administrator for global materials security at DOE's National Nuclear Security Administration (NNSA), in 6 February testimony to the House Energy and Commerce Committee.

A 2015 DOE report to Congress stated that for $1.1 billion, the nation can obtain enough LEU for tritium production until 2038. The department estimates it will need fresh HEU for naval reactors by 2060.

Officials at NNSA haven't said how soon action is required. But former DOE deputy secretary Daniel Poneman says that DOE nuclear facilities typically have taken about 15 years to build, with design and licensing approval likely adding several more years.

The dual-use conundrum

Tritium is used to boost the fissioning of plutonium in the primary stage of nuclear weapons. With a half-life of 12.5 years, it must be replenished in warheads every five years or so. DOE produces tritium by irradiating lithium-containing materials in one of the two LEU-fueled reactors at the Watts Bar, Tennessee, nuclear-power-generation plant owned by the quasi-governmental Tennessee Valley Authority (TVA). The isotope is then purified and loaded into warhead canisters at an NNSA site. The agency plans to step up tritium production by using a reactor at a second TVA plant beginning in 2022.

Although LEU is plentiful and widely available on the market, there's a big catch: US nonproliferation policy stipulates that the uranium used for tritium production be enriched domestically using US-origin technology. It's part of an overarching dual-use policy that with major exceptions since the 1950s has prohibited the mingling of US military and civilian nuclear programs. For uranium enrichment, however, US dual-use policy has been applied just one way: Government-owned enrichment plants, built for military purposes, also have supplied the commercial nuclear industry since the 1950s.

For NNSA planners, though, the problem is that the US has lacked a domestically developed enrichment technology since a plant in Paducah, Kentucky, closed for good in 2013. Like other closed DOE enrichment plants, Paducah used gaseous diffusion, a Manhattan Project–era technology that couldn't compete commercially with the more modern centrifuge-enrichment method.

In addition to tritium for weapons and HEU for naval reactors, DOE has identified a third enrichment need: high-assay LEU, material enriched to a level just below the 20% ^{235}U threshold that delineates HEU. Supplies of high-assay LEU, used by foreign and domestic research reactors and in the development of advanced reactors, could run out as soon as 2025, the agency says. Although high-assay material isn't for military purposes and thus is not subject to dual-use restrictions, no commercial plants in the world currently produce uranium enriched to that level.

The sole domestic enrichment plant, Urenco USA, employs centrifuge technology developed by its owners, a Dutch-German-UK consortium. The partner governments of the New Mexico facility have interpreted their nonproliferation agreement with the US to not exclude US use of LEU from there for tritium production, inasmuch as they consider tritium to be a byproduct of the TVA reactors' power generation. The US interpretation does not allow the byproduct argument.

DOE anticipates that it can obtain enough eligible LEU to sustain tritium production until at least 2038. Some of the material would come from downblending surplus HEU—diluting it with natural uranium to reach reactor-grade LEU, at an estimated cost of $1.1 billion. Other LEU would come from remaining US-origin stocks and by swapping LEU produced abroad with US-flagged material that's still held by the nuclear industry. The flag exchange is an accounting measure that doesn't entail actual physical transfers of LEU, which is fungible.

The exact quantity of HEU held by the government is a secret. But in an unusual 2016 declaration, President Barack Obama stated that the HEU stockpile stood at 585.6 metric tons in September 2013. As of that date, 500 tons was either contained in or designated for weapons, or reserved for naval reactor fuel, high-assay nuclear fuel, or scientific applications. The remainder was available for downblending to LEU or was contained in spent fuel and other waste.

In its most recent update, the nonprofit International Panel on Fissile Materials estimates that at the end of 2014, the US HEU stockpile stood at 567 tons, with 116 tons reserved for naval reactors and 20 tons kept for high-assay reactor fuel.

Frank von Hippel, an emeritus professor at Princeton University who advocates for a global ban on HEU production, estimates that DOE has 100 tons of HEU that it hasn't counted in its inventory of material available for downblending to LEU. Contained in what's known as a strategic reserve, that HEU consists primarily of components of dismantled weapons stored in Oak Ridge, Tennessee. With that material, the US could extend tritium production through 2060, he says. Enough HEU would be left to maintain an arsenal of 4500 weapons, well beyond the limit of 1550 deployed warheads established by the 2011 New START Treaty with Russia. But downblending strategic-reserve HEU would require revision of a 2011 presidential directive.


DOE

A "BUTTON" OF HIGHLY ENRICHED URANIUM metal. HEU comes in various forms, including oxides, solutions, and new or irradiated reactor fuel. All HEU is considered weapons usable.

Examining options

Representatives of some 15 businesses attended a November conference convened by DOE's NNSA to discuss "new or innovative mutually beneficial contracting arrangements and strategies" for providing LEU for tritium. An NNSA official describes the day-long meeting, from which the press was excluded, as "market research." No decision has been made on how the agency will proceed, and no request for proposals is currently planned, the official says. She declines to name the companies that were represented.

Poneman is now CEO of Centrus Energy, a US uranium broker that emerged from the Chapter 11 bankruptcy of the United States Enrichment Corp. USEC operated the shuttered Paducah plant and another gaseous diffusion plant that closed in 2001. "I call us a once and future producer," Poneman says.

With DOE, Centrus developed a centrifuge technology known as AC100. DOE has stated that the AC100 is the most technically advanced and least-risk option to use for a new enrichment plant. The 2015 DOE report estimated the cost of a plant fully equipped with the required 1440 AC100 centrifuges at $3.1 billion to $4.8 billion, assuming operations would commence in 2022. The price tag could swell to $11.3 billion if construction is delayed until 2022 and stretched out over 13 years to minimize annual appropriations, the report said. Annual operating costs were estimated at $112 million to $195 million.

From those DOE estimates, von Hippel calculates that an AC100 plant built to meet defense needs would produce LEU at a cost ranging from $277 to $618 per separative work unit (SWU), which is a measure of the effort needed to enrich uranium. The historical average market price is about $100/SWU, but a glut of LEU on the market has pushed prices down to below $40/SWU recently.

Commercial enrichers have lower SWU costs due to their much larger plant capacities (typically 5 million SWU/year compared with the hypothetical DOE plant's 400 000 SWU/year). Poneman says he would favor constructing an enrichment plant that's big enough to also supply the commercial sector.

The legislation that turned over the DOE enrichment plants to USEC in 1992 included a provision barring the government from reentering the commercial enrichment market. To serve both civilian nuclear industry and defense needs, a new plant would have to be privately owned and operated.

Centrus operated a pilot plant of 120 AC100 centrifuges in a three-year demonstration completed in 2016. Under a long-standing contract that was renewed in October 2017, Centrus continues to refine the technology at a facility in Oak Ridge. Although some components of the pilot plant were manufactured abroad, a Centrus spokesperson says the company has identified US sources for all of them.

Oak Ridge National Laboratory is developing a separate enrichment technology that uses smaller centrifuges. The 2015 DOE report estimated that a plant based on the lab's technology could cost $3.2 billion to $6.8 billion, with operating costs similar to those of the AC100. But since those centrifuges haven't been tested, there is less confidence in that prediction.

Additional options for extending the tritium supply were discussed in the 2015 report but were rejected as prohibitively costly or insufficiently developed. They included reprocessing DOE spent-fuel inventories, producing tritium in an accelerator, and separating uranium isotopes electromagnetically or with lasers.

Centrus may appear to have a considerable advantage should DOE decide to solicit bids to build an enrichment plant. But the agency holds the intellectual property rights to the AC100 technology and could license it to another contractor, the NNSA official says.

Before it could proceed to construct a new enrichment plant, DOE would have to prepare an environmental impact statement that evaluates both the plant and its alternatives. Options could include blending down strategic reserve HEU, reconsidering the ban on foreign-origin LEU, and doing nothing.

A blurred line

Poneman, who was in charge of US nonproliferation and export control policy at the National Security Council during the 1990s, strongly backs continuance of the dual-use ban on LEU for tritium. The US would lose its global leadership in nonproliferation policy if it were to cross the civilian–military line, he says. "To say [Urenco] are Europeans, we like them, so let's ignore peaceful-use restrictions, and then expect anyone else around the world to respect peaceful-use restrictions, I don't think is good policy," he says. "Hunting around trying to find loopholes and then pontificating to India and Iran 'watch what we say, not what we do' strikes me as the height of hypocrisy."

Having supplied the nuclear industry with LEU since the 1950s, the government again crossed the dual-use divide in 1999 when it elected to use the TVA reactors for tritium production rather than build a dedicated reactor. Nuclear proliferation wasn't a big concern when DOE began fueling the nuclear industry, and the US routinely supplied weapons-grade HEU to fuel foreign and domestic research reactors. More recently, DOE has been proactively taking back HEU research reactor fuel and helping convert research reactors to LEU (see PHYSICS TODAY, April 2016, page 28).

Von Hippel believes it's important to keep peaceful and weapons uses distinct, "and then shrink the boundary around the weapons activities—ultimately to zero." He wouldn't object in principle to a new enrichment plant to provide for tritium and naval reactors—as long as it didn't produce HEU. That would mean the US Navy would have to convert its reactor fleet to operate on LEU fuels before the HEU stockpile is depleted—an optimistic assumption, he admits.

France's and China's nuclear navies operate with LEU, and in the US, the navy has been prodded by some lawmakers in recent years to explore conversion. But HEU offers a distinct advantage for the navy's future submarine designs: reactor cores that won't require refueling throughout a ship's lifetime.

Edwin Lyman of the Union of Concerned Scientists says building a new enrichment facility for weapons, particularly one to eventually produce weapons-grade HEU, would be a bigger proliferation concern than using foreign-origin LEU for tritium. "A dedicated military enrichment plant, outside of [International Atomic Energy Agency] safeguards," he says, "would send a worse signal than the US saying we're going to interpret our peaceful-use obligations very narrowly" to match Urenco's position.

David Kramer PT