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URANIUM MANAGEMENT

Actions to Mitigate Risks to Domestic Supply Chain Could Be Better Planned and Coordinated

GAO-21-28

GAO Highlights

Highlights of GAO-21-28, a report to congressional committees

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Why GAO Did This Study

NNSA has several defense needs for enriched uranium, including low-enriched uranium to produce tritium for nuclear weapons. To meet these needs, NNSA relies on commercial sectors of the domestic uranium industry, such as uranium mining or enrichment, which make up a supply chain for unobligated uranium. However, this industry faces commercial viability risks. In April 2020, the President's Nuclear Fuel Working Group released a strategy to mitigate risks to the domestic uranium industry. This working group includes DOE, the Department of Defense, and other agencies.

Senate Report 115-262 included a provision that GAO review NNSA's planning for the future supply of unobligated enriched uranium. This report examines (1) risks agencies and others have identified to the unobligated uranium supply chain and agency actions to mitigate those risks, and (2) the extent to which the Nuclear Fuel Working Group's risk mitigation strategy incorporates desirable characteristics of a national strategy. GAO analyzed key NNSA and DOE planning documents and interviewed NNSA and other agency officials and industry representatives.

What GAO Recommends

GAO is making three recommendations, including that DOE improve its cost estimate to support future funding requests for the proposed uranium reserve and ensure its implementation plan for the strategy addresses each of the desirable characteristics of a national strategy. DOE concurred with GAO's recommendations.

View GAO-21-28. For more information, contact. Allison Bawden at (202) 512-3821 or bawdena@gao.gov.

What GAO Found

Federal agencies, including the Department of Energy (DOE) and the separately organized National Nuclear Security Administration (NNSA) within DOE, and uranium industry representatives have identified risks to the commercial supply chain for uranium needed for defense purposes. Such uranium may need to be mined domestically and enriched using U.S. technology to be free of obligations for the peaceful use of uranium and certain technology imported under international agreements. Identified risks to the unobligated uranium supply chain include (1) possible loss of domestic uranium mining capabilities and (2) possible challenges in re-starting the only facility in the United States for converting natural uranium into a form suitable for use in enrichment operations. Further, the U.S. has not had an operating enrichment capability that uses U.S. technology since 2013.

Idle Domestic Plant for Converting Uranium to a Form Suitable for Enrichment

Source: ConverDyn. | GAO-21-28

DOE and NNSA have initiated actions officials believe will mitigate such risks to the unobligated uranium supply chain. For example, DOE and NNSA have both taken steps to reestablish a domestic enrichment capability with U.S. technology. In addition, DOE has proposed creation of a domestic uranium reserve to help support the domestic uranium mining and conversion industries until market conditions improve. DOE's fiscal year 2021 budget request includes $150 million for the reserve. However, we cannot conclude that the estimate is reasonable because it is unclear how the funding needs for the reserve were determined. By providing a more complete analysis to support future funding requests for the reserve, DOE could better provide assurance that such requests would achieve objectives.

The Nuclear Fuel Working Group's strategy to mitigate risks to the domestic uranium industry does not fully incorporate all desirable characteristics GAO has identified for a national strategy. For example, it does not identify (1) the level of resources needed to support proposed actions or (2) an interagency coordinating mechanism. DOE is developing an implementation plan for the strategy, but DOE officials provided conflicting statements about the extent to which the agency will coordinate interagency implementation.

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Abbreviations

AOA	Analysis of Alternatives
Centrus	Centrus Energy Corporation
Commerce	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOE-NE	Department of Energy, Office of Nuclear Energy
HALEU	high-assay low-enriched uranium
HEU	highly enriched uranium
ISR	in-situ recovery
LEU	low-enriched uranium
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
State	Department of State
TPBAR	tritium-producing burnable absorber rods
TVA	Tennessee Valley Authority
USEC	United States Enrichment Corporation

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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Congressional Committees

The National Nuclear Security Administration (NNSA), a separately organized agency within the Department of Energy (DOE), has responsibility for selected national security missions, including management of the nation's nuclear weapons stockpile and the Naval Nuclear Propulsion Program, which supports reactor design and production for the U.S. nuclear-powered naval fleet. These missions, including those for defense purposes, depend on a reliable supply of uranium.[1] Uranium is a naturally occurring radioactive element that must be processed for ultimate use as nuclear reactor fuel. Such processing is part of the nuclear fuel cycle.[2] The nuclear fuel cycle includes front-end steps, such as mining and milling of uranium ore, converting the uranium to a chemical form suitable for enrichment, enriching the uranium (whereby the concentration of the fissile isotope uranium-235 in the uranium is increased),[3] and fabricating the enriched uranium into nuclear fuel.

Near-term requirements for defense purposes include supplying low-enriched uranium (LEU) to power nuclear reactors that produce tritium for nuclear weapons.[4] Longer-term requirements include supplying highly enriched uranium (HEU) to fuel the reactors that power the U.S. Navy's aircraft carriers and submarines and to maintain the nuclear weapons

[1]The term "national security" can be used to encompass defense, energy, economic, and other issues.

[2]The nuclear fuel cycle is the cradle-to-grave life cycle from extracting uranium ore from the earth through power production in a nuclear reactor to permanent disposal of the resulting spent nuclear fuel. The front end of the nuclear fuel cycle includes the portion of the nuclear fuel cycle leading up to electrical power production in a nuclear reactor. The front end of the nuclear fuel cycle has four stages: mining and milling, conversion, enrichment, and fabrication.

[3]Uranium-235 is the fissionable isotope of uranium that can sustain a chain reaction to release large amounts of energy. Isotopes are varieties of a given chemical element with the same number of protons but different numbers of neutrons.

[4]Tritium is a radioactive isotope of hydrogen used to enhance the power of nuclear weapons.

stockpile.[5] Use of uranium for such purposes is affected by obligations to foreign partners that uranium and enrichment technology be used only for peaceful purposes.[6] These obligations are stipulated in international agreements, such as nuclear cooperation agreements, that the United States enters into with foreign governments regarding nuclear commerce. Material and technology not subject to such obligations are referred to as "unobligated," while material and technology with obligations attached are referred to as "obligated."

To meet national needs for unobligated uranium, the United States has relied on private companies comprising a domestic uranium industrial base. This industrial base includes the companies involved in each step of the front end of the nuclear fuel cycle. The products that these companies produce (such as uranium ore or enriched uranium) are part of the uranium supply chain, a network between the suppliers who produce and distribute a specific product and the end users of that product.

The last uranium enrichment plant in the United States to use unobligated enrichment technology ceased operating in 2013.[7] As a result, the United States is not currently producing unobligated enriched uranium. NNSA's needs for enriched uranium are currently fulfilled via the U. S.' remaining inventory, which is a finite and currently irreplaceable source. NNSA expects this inventory to meet needs for LEU until the early 2040s and for HEU until the 2050s. NNSA is currently conducting an analysis of alternatives (AOA) process to evaluate options for reestablishing a domestic uranium enrichment capability to meet longer-term defense

[5]Uranium is categorized by concentration of the isotope uranium-235, expressed as a percentage "assay." Natural uranium must be enriched to increase its assay to the level required for a certain purpose. LEU, which is typically used in commercial nuclear reactors, has an assay of between 0.7 percent and 20 percent. HEU has an assay level greater than 20 percent.

[6]In 2014, we reviewed international agreements addressing enrichment technology in the United States with respect to how peaceful use provisions apply to tritium production. See GAO, *Department of Energy: Interagency Review Needed to Update U.S. Position on Enriched Uranium That Can Be Used for Tritium Production,* GAO-15-123 (Washington, D.C.: Oct. 14, 2014). GAO recommended that the Secretary of Energy work through an interagency working group to review DOE's current practice of using only unobligated LEU for the production of tritium. This recommendation has been implemented and closed.

[7]The Paducah Gaseous Diffusion Plant, in Paducah, Kentucky, was constructed and began enriching uranium in the 1950s and ceased operations in 2013 because of high production costs, coupled with a global drop in demand for enrichment services.

needs for unobligated enriched uranium. In 2018, we found shortcomings in NNSA's mission needs statement for the AOA and in its preliminary cost estimates for the two leading enrichment options.[8]

At the request of two U.S. mining companies, the Department of Commerce (Commerce) conducted an investigation, referred to as a Section 232 investigation, into the effect of imports of uranium on national security.[9] In response to the results of Commerce's investigation, which the agency sent to the White House in April 2019, the President established a Nuclear Fuel Working Group in July 2019 to develop recommendations for reviving and expanding domestic nuclear fuel production. The group was co-chaired by the Assistant to the President for National Security Affairs and the Assistant to the President for Economic Policy. It consisted of leaders from executive agencies, including the Department of Defense (DOD), DOE, Commerce, and the Department of State (State).[10] DOE released the working group's strategy, *Restoring America's Competitive Nuclear Energy Advantage: A Strategy to Assure U.S. National Security,* in April 2020.[11] The strategy outlines potential actions intended to revive capabilities of the domestic uranium mining, milling, and conversion sectors, among other objectives.

[8]GAO, *Nuclear Weapons: NNSA Should Clarify Long-Term Enrichment Mission Needs and Improve Technology Cost Estimates,* GAO-18-126 (Washington, D.C.: Feb. 16, 2018). We recommended that NNSA (1) revise the scope of its mission need statement and (2) ensure that the scope of its cost estimates aligns with the revised statement while developing estimates consistent with best practices. According to NNSA officials, NNSA does not intend to revise the scope of its mission need statement but is working to develop improved cost estimates as part of its ongoing AOA.

[9]Section 232 investigations are conducted under the authority of the Trade Expansion Act of 1962, as amended, and may be initiated based on an application from an interested party or a request from the head of any department or agency, or they may be self-initiated by the Secretary of Commerce.

[10]According to the presidential memorandum announcing the creation of the working group, the group included the following members or their designees: the Assistant to the President for National Security Affairs, serving as a co-chair; the Assistant to the President for Economic Policy, serving as the other co-chair; the Secretary of State; the Secretary of the Treasury; the Secretary of Defense; the Secretary of the Interior; the Secretary of Commerce; the Secretary of Energy; a designee of the Nuclear Regulatory Commission; a designee of the Federal Energy Regulatory Commission; the Director of the Office of Management and Budget; the Director of the Office of Science and Technology Policy; and the Chairman of the Council of Economic Advisers.

[11]Although the working group included representatives from other agencies, DOE published the strategy.

We have previously reported that complex interagency efforts can benefit from a national strategy. We have also identified a set of desirable characteristics that can guide responsible agencies in developing and implementing strategies—and enhance their usefulness in resource and policy decisions and better ensure accountability.[12]

Senate Report 115-262, accompanying a bill for the National Defense Authorization Act for fiscal year 2019, includes a provision for GAO to review NNSA's planning and assumptions for the future supply of unobligated enriched uranium. This report examines (1) the risks federal agencies and others have identified with respect to the supply chain for unobligated uranium, and agency actions to mitigate those risks; and (2) the extent to which the Nuclear Fuel Working Group's strategy for addressing risks to the domestic uranium industry incorporates desirable characteristics of a national strategy.

To examine the risks federal agencies and others have identified with respect to the supply chain for unobligated uranium, we reviewed relevant agency documents, such as the *2020 Stockpile Stewardship and Management Plan,* as well as information on Commerce's Section 232 investigation into the effects of uranium imports on national security.[13] Commerce officials did not provide us access to the Section 232 report, even though Commerce is required by law to publish it in the Federal Register,[14] because the report is the subject of ongoing litigation,[15] and Commerce officials assert that it contains privileged and confidential

[12]GAO, *Combating Terrorism: Evaluation of Selected Characteristics in National Strategies Related to Terrorism*, GAO-04-408T (Washington, D.C., Feb. 3, 2004). We identified the characteristics to aid responsible parties in further developing and implementing strategies related to terrorism and to enhance their usefulness in resource and policy decisions and better assure accountability. We identified them by consulting numerous sources, including legislative and executive branch guidance; the Government Performance and Results Act of 1993; other statutory requirements; general literature on strategic planning and performance; and guidance from the Office of Management and Budget.

[13]*The Stockpile Stewardship and Management Plan* is NNSA's formal means of communicating to Congress information on modernization and operational plans and budget estimates over the next 25 years. NNSA updates the plan annually.

[14]Specifically, Commerce is required to publish any portion of the report that does not contain classified or proprietary information in the *Federal Register.* 19 U.S.C. § 1862 (b)(3)(B).

[15]*Cause of Action Institute vs. U.S. Department of Commerce*, No. 1:19-cv-02698 (D.D.C. filed Sept. 9, 2019).

information.[16] To mitigate this denial and in order to complete our review within a time frame responsive to the needs of our congressional requesters, we instead requested written responses from Commerce officials about any risks to the unobligated uranium supply chain that were identified in the report. In their written response, Commerce officials were unable or unwilling to provide additional details beyond what was published in the presidential memorandum announcing the creation of the Nuclear Fuel Working Group and in the Nuclear Fuel Working Group's strategy. We reviewed the Nuclear Fuel Working Group's strategy to identify risks cited and actions recommended to mitigate risks. We interviewed officials from DOE, NNSA, DOD, Commerce, State, the Nuclear Regulatory Commission (NRC), and the Tennessee Valley Authority (TVA). In addition, we interviewed representatives from private companies involved in the nuclear fuel cycle and representatives from organizations that either promote or consult on the uranium industry to understand the state of the domestic uranium market. We also visited the sole uranium conversion facility in the United States, the Metropolis Works Plant owned by Honeywell International Inc., to understand the market conditions and technical issues affecting the plant's ability to operate.

To examine agency actions to mitigate risks to the unobligated uranium supply chain, we examined initiatives that had been proposed or funded prior to the release of the Nuclear Fuel Working Group's strategy in April 2020. We specifically examined DOE's proposal to establish a domestic uranium reserve and DOE and NNSA actions related to reestablishing domestic uranium enrichment capabilities. We reviewed documents describing these actions, such as the President's fiscal year 2021 budget and DOE's fiscal year 2021 budget justification, for details regarding the proposed domestic uranium reserve; NNSA's mission needs statement for its domestic uranium enrichment AOA; documentation pertaining to a DOE contract to demonstrate enrichment technology; and available information on Commerce's Section 232 investigation. We also reviewed the Nuclear Fuel Working Group's strategy to better understand the basis for the reserve and to identify additional potential actions. In addition, we interviewed officials from NNSA and from DOE's Office of Nuclear Energy (DOE-NE) regarding the uranium reserve and actions to reestablish domestic enrichment capabilities. We assessed the actions that NNSA and DOE had proposed or undertaken against DOE and NNSA directives.

[16]Agency claims of privilege or confidentiality are not a bar to GAO's right of access to information under 31 U.S.C. § 716.

To address the extent to which the Nuclear Fuel Working Group's strategy incorporates desirable characteristics for national strategies, we reviewed the strategy and compared it to a set of desirable characteristics for national strategies that we identified in previous work.[17] These characteristics are (1) purpose, scope, and methodology; (2) problem definition and risk assessment; (3) goals, subordinate objectives, activities, and performance measures; (4) resources, investments, and risk management; (5) organizational roles, responsibilities, and coordination; and (6) integration and implementation. As part of our review, two reviewers independently assessed the strategy to determine the extent to which the desirable characteristics were addressed by the strategy and reconciled any differences. We considered the strategy to be "consistent" if it addressed a desirable characteristic without significant gaps in coverage of the elements associated with the characteristic; "partially consistent" if it addressed a desirable characteristic with significant gaps in coverage of the elements associated with the characteristic; and "not consistent" if it did not address a desirable characteristic or did not demonstrate coverage of the elements associated with the characteristic. We also interviewed officials from DOE to understand the interagency effort to develop this strategy. National Security Council staff responded to written questions we asked about the working group's status and about future plans related to implementation of the strategy.

We conducted this performance audit from November 2018 to December 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Uranium and the Nuclear Fuel Cycle

Uranium is a naturally occurring radioactive element that can be enriched to fuel nuclear reactors and for certain defense purposes. It is categorized by concentration of the isotope uranium-235, expressed as a percentage "assay." Natural uranium consists of approximately 99.3 percent of the isotope uranium-238 and 0.7 percent of the isotope uranium-235. Uranium that has been enriched has a higher assay level of uranium-235.

[17]GAO-04-408T.

Uranium with different assay levels is used for different purposes (see table 1).

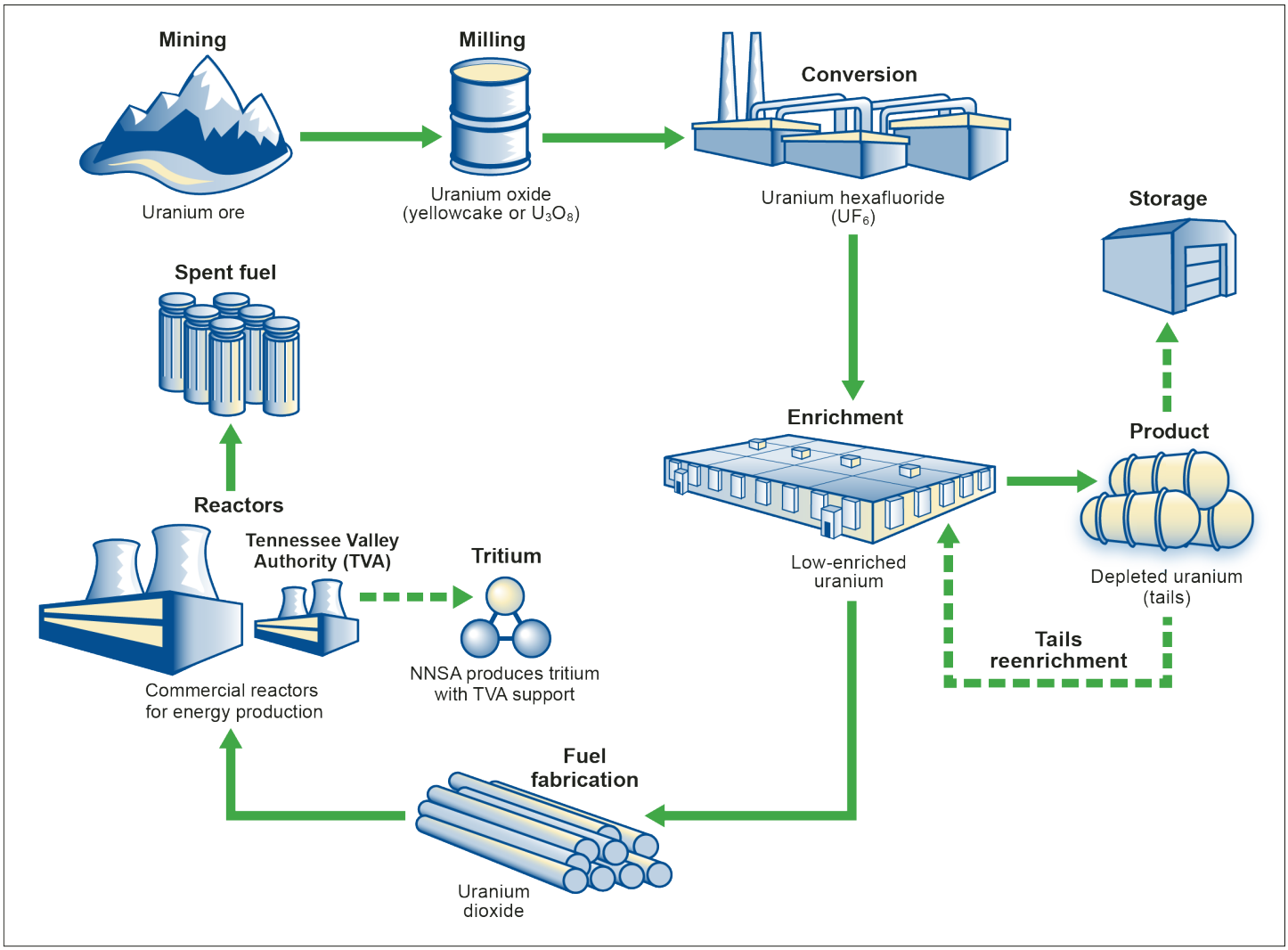
Table 1: Types of Uranium and Their Uses

Type	Assay level of uranium-235	Examples of uses
“Tails” (depleted uranium)	Up to 0.7 percent	Tails have historically been viewed as a waste product because considerable enrichment processing is required to extract the remaining useful quantities of uranium-235. However, in some cases, it may be profitable or necessary to reenrich “high-assay” tails. Most enrichers are enriching tails to utilize excess centrifuge enrichment capability. Some depleted uranium may be of value to the market, depending on the assay level, cost to reenrich, and other market conditions.
Natural uranium	0.7 percent	Natural uranium may be used for fuel in certain foreign nuclear reactor designs; otherwise, it is enriched for the uses described below.
Low-enriched uranium (LEU)	Greater than 0.7 percent and less than 20 percent	LEU is used in commercial nuclear power plants at assay levels generally between 3 percent and 5 percent.
High-assay low-enriched uranium (HALEU)	Greater than 5 percent and less than 20 percent	Advanced reactor designs (including small modular reactors and microreactors) and potential future Department of Defense mobile nuclear power plant designs may require HALEU fuel. The National Nuclear Security Administration also requires HALEU for research and isotope production reactors.
Highly enriched uranium (HEU)	20 percent or greater	HEU is used in nuclear weapons, in the reactors that power naval propulsion, and in some research reactors. Weapons-grade HEU generally has an assay level of at least 90 percent. HEU can be downblended by mixing it with depleted uranium, natural uranium, or LEU to convert it into a new product that is less than 20 percent uranium-235.

Sources: GAO analysis of documents from the Department of Energy, the Nuclear Regulatory Commission, USEC Inc., and others. | GAO-21-28

Generally, to produce enriched uranium fuel, natural uranium is extracted or mined from underground deposits; converted from a solid to a gas; enriched to increase its concentration of uranium-235; and then fabricated into fuel elements appropriate for their ultimate use, such as rods for commercial nuclear reactors. These steps make up the front end of the nuclear fuel cycle (see fig. 1).

Figure 1: Nuclear Fuel Cycle



Sources: GAO analysis of International Atomic Energy Agency , Nuclear Regulatory Commission, Congressional Research Service, Department of Energy, and Tennessee Valley Authority documents. | GAO-21-28

Note: This figure does not depict reprocessing of spent fuel. While there are no commercial reprocessing facilities currently operating in the United States, other countries, such as France, Japan, and Russia, do have these capabilities.

- **Mining:** The nuclear fuel cycle begins with the mining of uranium. Mining may be done through conventional methods (which include surface mining, open pit mining, and underground mining) or in-situ recovery (ISR) methods that involve pumping acid or alkaline solutions through an underground ore body to leach out and recover

uranium. ISR methods can recover uranium from lower-grade ores and with less surface disturbance than conventional methods. ISR methods result in a product that can be sent directly to a uranium conversion facility rather than a milling facility. In the United States, ISR methods have generally replaced conventional mining and milling.

- **Milling:** Uranium ore extracted through conventional mining methods goes to a milling facility, where it is crushed and concentrated. The milled uranium is purchased by utility companies and shipped to a conversion facility.
- **Conversion:** At a conversion facility, the uranium is converted into a form suitable for use in enrichment operations. Specifically, it is combined with fluorine gas to produce uranium hexafluoride, which is a powder at room temperature and a gas when heated.
- **Enrichment:** The enrichment process increases the concentration of uranium-235 in the uranium hexafluoride. The only uranium enrichment technology in operation today is gas centrifuge technology, which works by spinning uranium hexafluoride in a gaseous form inside a centrifuge at an extremely high speed.[18] The enrichment process results in two principal products: (1) enriched uranium hexafluoride, which can be further processed for specific uses, such as for use in nuclear weapon components or fuel for nuclear power plants; and (2) leftover "tails" of uranium hexafluoride. These tails are also known as depleted uranium because the material is depleted in uranium-235 compared with natural uranium. Most tails are stored for future disposal, although in some cases it may be profitable to reenrich them.

After enriched uranium has been fabricated into fuel and used in a nuclear power plant, it is considered "spent" nuclear fuel. Currently, in the United States, spent fuel from commercial nuclear power plants is stored until a permanent disposal solution is determined.

State of the Domestic Uranium Industry

The United States generates more nuclear power than any country worldwide. As of July 2020, 95 nuclear reactors were operating at 57 nuclear power plants in 29 states. These nuclear power plants generate

[18]Other technologies include gaseous diffusion, which involves passing uranium hexafluoride in a gaseous form through a series of filters and then cooling it into a solid, and laser separation enrichment, which uses lasers to separate isotopes. Historically, gaseous diffusion was used. Ongoing research into and development of various laser technologies is being conducted.

approximately 20 percent of the country's electricity. However, the domestic uranium industry faces several challenges:

- **Uncertain future of nuclear power.** U.S. nuclear power plants face economic pressures and a general uncertainty over their long-term economic viability. In 2015, we issued a technology assessment on nuclear reactors that reported that commercial nuclear reactors are aging, and some have shut down prior to license expiration because of economic pressures in certain markets.[19] The newest reactor to enter service is TVA's Watts Bar Unit 2, which began operation in June 2016. Prior to that, the most recent reactor to enter service was Watts Bar Unit 1 in May 1996. There are two nuclear power reactors under construction in the United States, with expected in-service dates of November 2021 and November 2022.
- **Oversupply of uranium.** An oversupply of uranium has resulted in a lower market price. According to industry documentation, uranium spot prices fell from a high of $136 in June 2007 to $33.25 in April 2020.[20] Some oversupply is a result of reduced demand.[21] Additionally, DOE maintains excess inventories of various types of uranium materials, which it has used to pay for services to support the cleanup of a former government-owned uranium enrichment facility. We have previously found that DOE sales or transfers of uranium have the potential to adversely impact the domestic uranium industry, and we issued five reports, four testimonies, and a legal opinion on such sales and transfers from July 2006 through March 2017.[22] In

[19]GAO, *Technology Assessment: Nuclear Reactors: Status and Challenges in Development and Deployment of New Commercial Concepts*, GAO-15-652 (Washington, D.C.: July 28, 2015). This product did not contain recommendations.

[20]The Energy Information Administration defines spot contracts as contracts with a one-time uranium delivery for the entire contract, and the delivery typically occurs within 1 year of contract execution.

[21]Recently, global demand for uranium has been depressed due to a number of factors, including the continued shutdown of most Japanese nuclear power reactors following the Fukushima Daiichi accident in 2011. Additionally, Germany, which had previously generated about 30 percent of its electricity with nuclear power, closed eight of the country's 17 power reactors and decided to shut the remainder by 2022.

[22]These products are referenced in our most recent testimony. See GAO, *Department of Energy: Excess Uranium Transfers*, GAO-17-472T (Washington, D.C.: Mar. 8, 2017). This testimony did not include new recommendations.

recent years, Congress has taken action on DOE's uranium transfers.[23]

- **Competition from foreign uranium suppliers.** Foreign competition has affected uranium production in the United States. According to a 2019 White House memorandum, increased production by foreign state-owned enterprises has distorted global uranium prices and made it more difficult for domestic mines to compete. In 2019, 93 percent of the uranium used in domestic nuclear reactors was of foreign origin. Issues related to foreign competition are not new. For example, the United States has recognized the effects of foreign competition on the domestic uranium market since at least 1991, when the U.S. International Trade Commission made a preliminary determination that industry in the United States was materially injured by imports of uranium from the Soviet Union. Since 1992, the United States and Russia have had an agreement, known as the Russian Suspension Agreement, to restrict the volume of uranium imports from Russia to protect U.S. industry. In October, 2020, Commerce announced an extension of the agreement through 2040.

U.S. Agencies Involved in Uranium Management Issues

Several U.S. agencies play a role in managing uranium:

- **NNSA.** NNSA, a separately organized agency within DOE, is responsible for the management of the nation's nuclear weapons stockpile, as well as for nonproliferation programs and the Naval Nuclear Propulsion program, which supports reactor design and production for the U.S. nuclear-powered naval fleet. Uranium, at various levels of enrichment, is important for all of these missions. NNSA meets several identified needs for enriched uranium, including (1) producing tritium through a process supported by TVA reactors using an existing inventory of unobligated LEU; (2) supplying HEU from excess dismantled nuclear weapons to meet the U.S. Navy's needs for its nuclear-powered aircraft carriers and submarines; and (3) providing high-assay low-enriched uranium (HALEU) for medical isotope production and research reactors.

[23]The conference report accompanying the Energy and Water, Legislative Branch, and Military Construction and Veterans Affairs Appropriations Act, 2019, directs that DOE shall not barter, transfer, or sell uranium to pay for the cleanup of a former federal uranium enrichment facility and explains that the agency's appropriation includes $60 million above its request in lieu of the proceeds that were anticipated from such transactions. H.R. Rep. No. 115-929 at 160 (2018). Additionally, the Nuclear Fuel Working Group's strategy states that DOE will cease bartering uranium.

- **DOE-NE.** DOE-NE's mission is to advance nuclear power to meet the nation's energy, environmental, and national security needs. DOE-NE describes its mission as including conducting early-stage research, development, and demonstration in an effort to enhance the long-term viability and competitiveness of the existing commercial U.S. reactor fleet; developing an advanced reactor pipeline; and implementing and maintaining national fuel cycle and supply chain infrastructure.
- **DOD.** DOD generates military requirements for nuclear warheads. DOD also requires HEU fuel supplied by NNSA for the Navy's nuclear-powered aircraft carriers and submarines. In addition, DOD is developing microreactors, which will require HALEU fuel.[24] According to DOD and DOE officials, the U.S. government has not yet made a determination as to whether the required HALEU must be unobligated.
- **Commerce.** Commerce's Bureau of Industry and Security conducts Section 232 investigations under the authority of the Trade Expansion Act of 1962, as amended. In 2019, the Bureau of Industry and Security completed a Section 232 investigation that examined the effects of uranium imports on national security. The mission of Commerce's International Trade Administration is to safeguard and enhance the competitive strength of U.S. industries against unfair trade and is responsible for negotiating and administering international trade agreements such as suspension agreements. As called for in the Nuclear Fuel Working Group Strategy, the International Trade Administration worked to extend the Russian Suspension Agreement to mitigate risks to the uranium supply chain and reduce U.S. reliance on uranium from Russia.
- **TVA.** At present, tritium is produced for NNSA in part through the use of one of TVA's electricity-producing nuclear reactors fueled with unobligated LEU. Small quantities of tritium are the normal by-products of electricity-producing nuclear power plants, such as those owned and operated by TVA. To capture and concentrate the tritium, specially designed absorbers—called tritium-producing burnable absorber rods (TPBAR)—are loaded with the unobligated LEU and irradiated in TVA's Watts Bar Unit 1 reactor. Irradiated TPBARs are unloaded during normal fuel reloading and shipped to NNSA's Tritium Extraction Facility at the Savannah River Site in South Carolina.

[24]For more information on microreactors, see GAO, *Science & Tech Spotlight: Nuclear Microreactors*, GAO-20-380SP (Washington, D.C.: February 2020). This spotlight does not contain recommendations.

- **State.** The Office of Nuclear Energy, Safety, and Security, within State's Bureau of International Security and Nonproliferation, develops U.S. policy on peaceful nuclear cooperation, nuclear safety, export controls, and the physical protection of nuclear materials and facilities.
- **NRC.** NRC regulates commercial nuclear power plants and other uses of nuclear materials, such as medical uses, through licensing, inspection, and enforcement of its requirements. In addition, jointly with NNSA, NRC co-sponsors the Nuclear Materials Management and Safeguards System, the government's official program to track movements, uses, and inventories of U.S. nuclear materials.[25]

Agencies Have Initiated Actions to Address Risks That They and Others Have Identified to the Supply Chain for Unobligated Uranium

Agencies and others have identified risks to the supply chain for unobligated uranium, and DOE and NNSA have initiated actions intended to mitigate such risks. Some of the risks were identified before the Nuclear Fuel Working Group issued its strategy. Of the agency actions to address these risks, one action is not fully planned, and others are not well coordinated across DOE and NNSA. Additional actions, which the working group proposed, are still early in planning.

Agencies and Others Identified Risks Related to the Unobligated Uranium Supply Chain Prior to the Issuance of the Nuclear Fuel Working Group's Strategy

In recent years preceding the issuance of the Nuclear Fuel Working Group's strategy, federal agencies and others have identified risks to the domestic uranium supply chain necessary to produce unobligated enriched uranium. Some of those risks have been identified in our prior

[25]For additional information on how the Nuclear Materials Management and Safeguards System is used to record uranium inventories and track obligations of this uranium under international agreements, see GAO, *Nuclear Material: Agencies Have Sound Procedures for Managing Exchanges but Could Improve Inventory Monitoring,* GAO-16-713 (Washington, D.C.: Sept. 23, 2016). GAO recommended that DOE and NRC clarify in guidance when facilities may carry negative obligation balances and develop an early-warning capability in the Nuclear Materials Management and Safeguards System to alert DOE when the inventory of unobligated LEU is particularly low. NRC and DOE have each implemented their respective recommendations.

reports. The risks described below have been identified for specific sectors of the domestic uranium supply chain:[26]

Mining and milling. To ensure that the United States can produce uranium for defense purposes without reliance on foreign countries, uranium must be mined and milled in the United States. In the 1950s, the United States had a large uranium mining industry that was supported by federal subsidies. Production of mined uranium peaked in 1980, when there were over 250 domestic mines in operation. However, by 2012, the number of operating mines dropped to 11, according to the U.S. Energy Information Administration. According to the Energy Information Administration's *Domestic Uranium Production Report 1st Quarter 2020*, released in May 2020, three U.S. mines were operating, and six were on standby.[27] Uranium mining production in the United States was 173,875 pounds in 2019, down approximately 88 percent from 2018. There are now four uranium mills located in the United States. Three are on standby, while one is still undeveloped.

Industry representatives identified the possible loss of domestic mining and milling capabilities in the future, due to uranium market pressures and trends, as a risk to the unobligated uranium supply chain. Commerce officials stated that because the uranium mining industry is global and is split between free-market and foreign state-owned enterprises, the uranium industry in free-market economies—such as in the United States—is struggling to compete, which has led to mine closures. Industry representatives said that foreign state-owned uranium supply entities are subsidized by their governments, enabling them to win bids to supply uranium to U.S. utilities and putting the domestic uranium mining sector at a competitive disadvantage. According to industry representatives, this foreign competition, in the form of less expensive foreign uranium, has caused domestic uranium producers to lose supply contracts.

Conversion. There is only one facility in the United States to convert milled uranium into a form suitable for use in enrichment operations. This facility—Honeywell's Metropolis Works Plant—has been on standby since November 2017. Industry representatives identified ongoing and future

[26]In this review, we identified risks to specific sectors of the supply chain that produce unobligated uranium, as well as more general risks and concerns about the health of the supply chain, through our review of agency documentation and interviews with agency officials and other stakeholders.

[27]A mine is described as being on standby when mining operations are not actively exploring or extracting uranium.

risks to the domestic uranium conversion capability due to uranium market pressures and trends. For instance, an industry representative from ConverDyn, the company that manages sales from the Metropolis Works Plant, stated that, unlike the foreign conversion market, in which facilities may be state owned, the U.S. conversion market does not have a guaranteed demand for its services. The Honeywell plant is currently on standby because, according to a company representative, the market is oversupplied with available foreign-sourced uranium that is already converted. The representative said that, while the company aims to restart operations at the plant, a restart is not guaranteed because of the market oversupply. In a response to a request for information that DOE issued in February 2020, ConverDyn reported that a restart would take about 24 to 30 months, with 18 to 24 months for NRC-required and Honeywell-mandated worker retraining. Some agency officials echoed these concerns, such as TVA officials who expressed concern about the long-term viability of the domestic conversion industry due to the market oversupply and foreign competition pressures.[28]

Enrichment. In 1993, the United States produced more than 90 percent of the enriched uranium that could be used in U.S. nuclear reactors; by 2008, it produced only 15 percent. Until 2013, uranium was enriched in the United States for national security, defense, and commercial purposes. In May 2013, USEC Inc.—which the U.S. government initially established in 1992 as a government corporation to operate DOE's enrichment facilities—ceased enrichment at its last commercially active enrichment plant in Paducah, Kentucky. USEC Inc., which has changed its name to the Centrus Energy Corporation (Centrus), has been the only company to enrich uranium with U.S. technology.[29] Louisiana Energy Services in Eunice, New Mexico, a wholly owned subsidiary of URENCO, owns the only operating enrichment facility in the United States, and it

[28]TVA and NNSA officials also noted that domestic mining, milling, and conversion services might not be needed to meet near-term defense needs for enriched uranium if a new domestic enrichment capability can use DOE's existing inventory of unobligated depleted uranium tails for feedstock. NNSA is considering using a portion of the tails as feedstock for a future production-scale enrichment facility. The viability of reenrichment depends on the assay and quality of the tails. According to NNSA officials, it would be possible to use these tails as feedstock.

[29]The company changed its name to Centrus Energy Corp. when it emerged from Chapter 11 bankruptcy in 2014.

uses European-developed technology that produces obligated enriched uranium.[30]

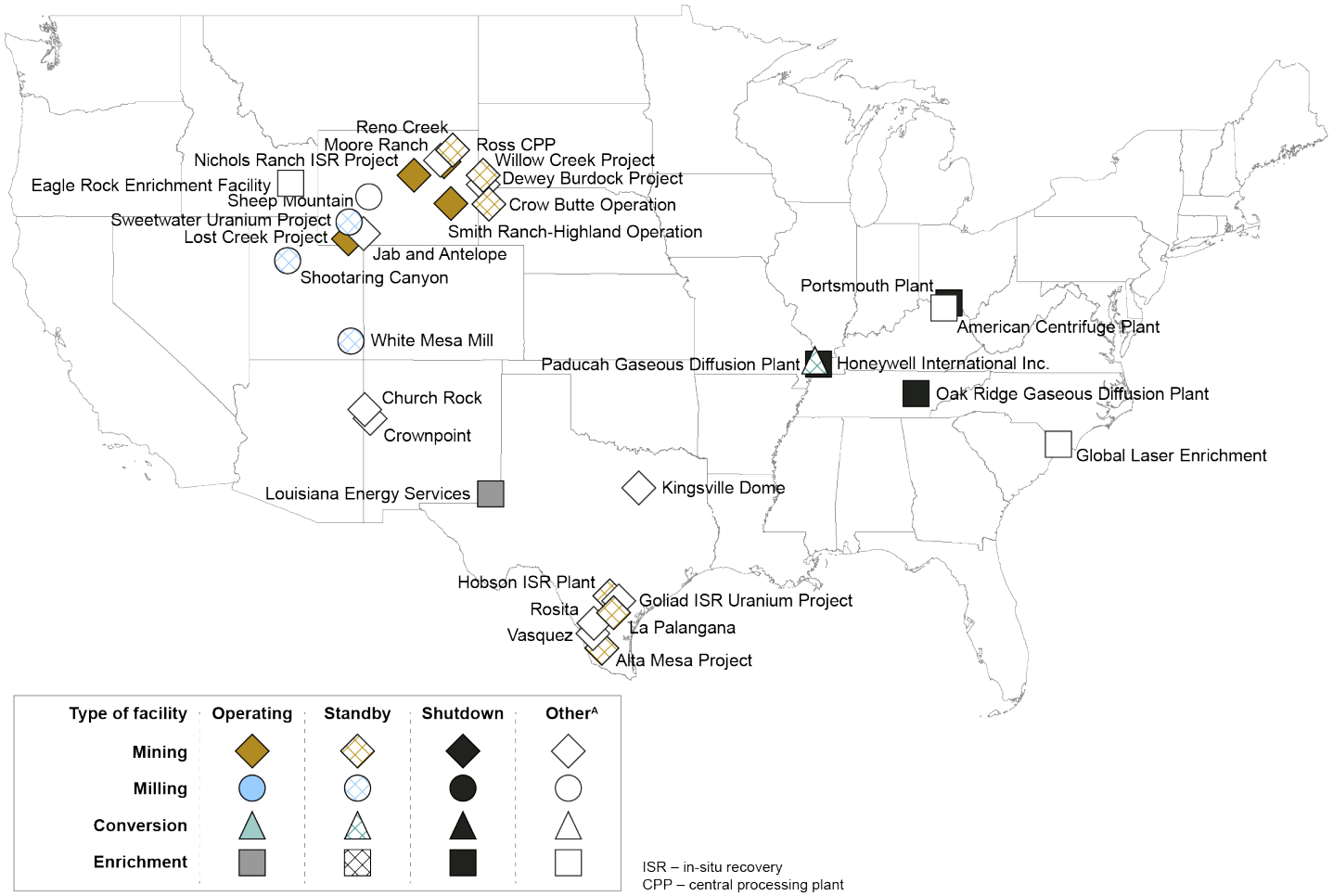
As we recently reported, NNSA has taken steps to preserve its inventories of unobligated uranium at different assay levels until a domestic enrichment capability can produce additional unobligated material.[31] NNSA officials we interviewed told us that existing U.S. stockpiles of HEU will be adequate to meet future nuclear weapons needs but that additional HEU production will be necessary by the 2050s to meet naval nuclear propulsion needs. NNSA's nearest-term need is for LEU used to meet stockpile needs for tritium. Restoring an enrichment capability for unobligated LEU for use in producing tritium is NNSA's priority with respect to the unobligated uranium supply chain. However, NNSA's needs for unobligated enriched uranium are relatively small compared with the large commercial uranium demands, which can be satisfied by obligated enriched uranium. NNSA's ongoing AOA process is therefore considering options for a government-built enrichment capability dedicated to meeting uranium requirements for defense purposes.

Figure 2 shows the location and operating status of all domestic mines, mills, uranium conversion facilities, and uranium enrichment plants.

[30]Louisiana Energy Services is a wholly owned subsidiary of URENCO, which is a consortium of companies owned or controlled by the British and Dutch governments and by two German utilities.

[31]GAO-18-126.

Figure 2: Location and Status of Uranium Facilities in the United States



Sources: GAO analysis of Energy Information Agency, Nuclear Regulatory Commission, and Department of Energy documents. | GAO-21-28

Notes: This figure shows facilities located in the United States, whether they are U.S. owned or foreign owned. The “other” category includes facilities that are not yet operational. The figure shows the status of facilities as of May 2020.

Agency officials we interviewed indicated that, because of risks such as those discussed above, they have concerns about the general health of the unobligated uranium supply chain and the effects that a failure of that chain could have on national security. For example, State officials we interviewed told us their agency is concerned about the strength of the domestic uranium industry and is monitoring it from a national security perspective. Similarly, DOD officials told us they are concerned about the domestic uranium industrial base because DOE needs unobligated enriched uranium to make weapons for DOD, and if that industry were to

fail, then DOD may need to support or subsidize domestic enriched uranium production.

Documents we reviewed from DOD, NNSA, and others also cited general supply chain concerns. For example, NNSA's October 2015 *Tritium and Enriched Uranium Management Plan through 2060* concluded that NNSA's national security missions require a reliable supply of enriched uranium in varying assays and forms, but the current supply is limited and irreplaceable until decisions are made to address shortfalls in supply and production capability. Similarly, the 2018 *Nuclear Posture Review* stated that the United States is unable to produce a number of critical materials, including enriched uranium. Similar concerns have been stated in NNSA's annual *Stockpile Stewardship and Management Plans*.

DOE and NNSA Have Initiated Actions to Mitigate Risks to the Unobligated Uranium Supply Chain, but One Action Was Not Fully Planned, and Others Are Not Well Coordinated

Prior to the release of the Nuclear Fuel Working Group strategy in April 2020, DOE and NNSA had initiated actions to mitigate risks to the unobligated uranium supply chain. These actions include a proposal to create a strategic uranium reserve and two ongoing actions intended to reestablish a domestic uranium enrichment capability. However, we found that the uranium reserve proposal was not fully planned, and the two ongoing actions to reestablish a domestic enrichment capability are not well coordinated, which could undermine the credibility of NNSA's ongoing AOA process to select such a capability.

Uranium Reserve

In its fiscal year 2021 budget justification, released in February 2020, DOE proposed $150 million in funding to create a domestic uranium reserve. According to the justification, the reserve is intended to provide assurance of uranium availability in the event of a market disruption; it is also expected to directly support the operation of at least two U.S. uranium mines and the reestablishment of active domestic conversion capabilities. According to DOE officials, providing a guaranteed demand for uranium through procurement for the reserve would keep domestic mining and conversion companies commercially viable so those companies could compete when the global uranium market improves.[32] While the reserve's express goal is not to provide unobligated uranium for defense needs, DOE officials told us that it would have the ancillary benefit of supporting the unobligated uranium supply chain by virtue of

[32]DOE officials expect that the excess inventories overhanging the uranium mining, conversion, and enrichment industries will be utilized, and advanced reactors will come online, increasing demand in the future.

the support it would provide to the domestic uranium mining and conversion sectors.

When the Nuclear Fuel Working Group's strategy was released in April 2020, it provided some additional information about the planned scope of and operations for the reserve. For instance, according to the strategy, the reserve will focus initially on supporting the mining sector but could be expanded to include the enrichment sector after pressure on mining is addressed. The strategy also proposes supporting the reserve over a 10-year period, which DOE believes reflects a responsible approach to addressing the challenges to the industry sectors making up the front end of the nuclear fuel cycle.

However, the $150 million fiscal year 2021 budget justification for the reserve is not based on a reasonable cost estimate. DOE officials stated that the $150 million proposed in the fiscal year 2021 budget justification was based on an estimate of how much money DOE officials believed would be required to create enough demand to keep some uranium production facilities operational in the near term. However, DOE officials could not provide supporting data on how the $150 million figure was calculated, and the working group strategy does not include such details. Additionally, DOE has not yet determined key details for establishing the reserve, such as the forms of uranium to be procured[33] and the rules for governing the reserve. According to DOE officials, DOE-NE is developing a high-level roadmap of actions that will help frame the time lines, provide specific program milestones, and underpin cost estimates for a future reserve.

However, DOE officials stated that section 301(a) of the Further Consolidated Appropriations Act precludes DOE from developing more specific information than was included in the budget justification or the strategy until the reserve is authorized and funding is appropriated. Section 301(a) prohibits DOE from initiating a program or taking certain specific steps, such as preparing Requests for Information, for programs

[33]DOE officials stated in July 2020 that while they expect the reserve to store material in the form of uranium hexafluoride, it has not been established whether procurement will be for natural uranium, uranium hexafluoride, or both.

that Congress has not funded.[34] DOE has not demonstrated, however, that developing a cost estimate for its budget justification would require DOE to initiate the program or take any precluded steps. For instance, the Office of Management and Budget's Circular A-11, *Preparation, Submission, and Execution of the Budget,* provides instructions to agencies on how to prepare and submit materials required for the Office of Management and Budget and presidential review of agency requests and for annual budget formulation.[35] Under these instructions, agencies must provide a written justification that should include the full cost of a program when submitting their budget. Moreover, DOE's own Order 130.1, *Budget Formulation,* requires that budget justifications be based on cost estimates that have been thoroughly reviewed and deemed reasonable.

In the absence of any documentation from DOE regarding how the $150 million budget estimate for the reserve was calculated to support the budget request made in February 2020, we cannot conclude that it is reasonable. Although DOE officials told us that they believe the reserve would continue to require approximately $150 million per year for 10 years, or about $1.5 billion over this period, officials did not provide information as to whether the reserve could be needed for longer. DOE officials told us that, if funding for the reserve is appropriated, they will further clarify details about the reserve, including rules for how the reserve would be governed. As DOE moves forward with establishing the reserve, documenting the basis for its cost estimate would provide assurance that DOE's funding requests to the Congress for the reserve are reasonable.

Enrichment Capability

To address identified risks to the enrichment sector, NNSA is currently evaluating a range of options to meet future demands for unobligated enriched uranium through an AOA process, consistent with DOE's policy

[34]Specifically, section 301(a) reads: "No appropriation, funds, or authority made available by this title for the Department of Energy shall be used to initiate or resume any program, project, or activity or to prepare or initiate Requests For Proposals or similar arrangements (including Requests for Quotations, Requests for Information, and Funding Opportunity Announcements) for a program, project, or activity if the program, project, or activity has not been funded by Congress." Pub. L. No. 116-94, 133 Stat. 2534 (2019). GAO has not evaluated DOE officials' interpretation of section 301(a).

[35]Office of Management and Budget, *Circular No. A-11, Preparation, Submission, and Execution of the Budget* (Washington, D.C., Executive Office of the President: July 2017).

for managing capital asset acquisitions.[36] Among the options are two centrifuge-based enrichment technologies: a small centrifuge technology currently under development at the Oak Ridge National Laboratory, and a large centrifuge technology under development by Centrus. NNSA planned to complete the AOA process at the end of 2020 and begin development of the selected technology to be available to provide enrichment services to meet national security needs by the late 2030s or early 2040s.[37]

DOE has also taken action to address identified risks to the enrichment sector. In October 2019, DOE definitized a sole source contract with Centrus for a 3-year period and a government cost share of up to $115 million for a demonstration project of its large centrifuge technology to produce HALEU, with the expectation that the technology would be commercialized following a successful demonstration.[38] According to DOE officials and documents, HALEU fuel will be needed for some types of commercial advanced reactors and for DOD microreactors. DOE officials stated that DOE-NE policy is to assist American companies in taking advantage of the emerging market for these types of reactors and their required fuel. No determination has been made as to whether any of these reactors, such as DOD's planned microreactors, may require HALEU fuel that is unobligated.[39] DOE officials stated that a successful demonstration of the ability to produce HALEU for advanced reactors and microreactors is important for proving the merits of the technology and the ability of American companies to provide this type of uranium.

However, DOE announced its HALEU demonstration contract with Centrus while NNSA's AOA for a possible future domestic enrichment

[36]Capital assets are land, structures, equipment, and intellectual property which are used by the federal government and have an estimated useful life of 2 years or more.

[37]We previously reported on the actions NNSA is taking to extend its existing LEU inventories to address near-term tritium needs and on NNSA's preliminary plan for analyzing options to supply unobligated enriched uranium in the long term. See GAO-18-126. According to NNSA officials in September 2020, NNSA has encountered a delay in completing the AOA and is working to revise its estimated completion date.

[38]DOE-NE is the office that is supporting the HALEU demonstration project.

[39]In January 2019, DOE issued a notice of intent indicating a need for unobligated HALEU for use in any type of advanced reactor application, civilian or defense related. However, a later addition to the notice of intent clarified that it was not DOE's position that U.S.-origin HALEU would be required for civilian advanced reactor applications. Additionally, an NNSA official told us in September 2019 that no government determination had been made as to whether certain defense-related reactors—such as DOD microreactors—would require unobligated HALEU.

capability was ongoing, raising questions about whether the projects had been sufficiently coordinated between DOE-NE and NNSA.

DOE officials stated that the DOE-NE and NNSA actions related to uranium enrichment were intentionally not coordinated because the projects have different goals and time lines. According to DOE officials, the HALEU demonstration project is focused on options for nearer-term commercial advanced reactor and DOD microreactor needs for HALEU; it is not intended to replace NNSA's ongoing AOA or to provide a technology solution for NNSA's unobligated enriched uranium needs. DOE officials said that the large centrifuge, if demonstrated successfully and commercialized, could also meet NNSA's future unobligated enriched uranium needs, but they told us that any benefit to NNSA in the future from the large centrifuge project would be coincidental, not by design.

Similarly, NNSA officials told us that they provided input into the DOE HALEU demonstration project to ensure that it would not adversely impact NNSA's AOA process and that the NNSA process is on a different time line. Additionally, NNSA officials said that the potential for commercialization is not a primary consideration in NNSA's selection of an option to meet future unobligated enriched uranium needs. NNSA officials stated that the significant difference in goals and schedules of the two actions restricts the scope that would be of benefit to both actions, but that they have pursued cooperation where the overlap exists.

Nevertheless, this approach to decision making may lead to a possibility that after DOE has awarded funding to the large centrifuge enrichment technology through the HALEU demonstration project, NNSA will select and seek to develop a different enrichment technology—such as the small centrifuge technology—as a result of its AOA process. NNSA and DOE officials acknowledged that the actions could result in the establishment of two different government-supported enrichment capabilities to produce unobligated enriched uranium. Consistent with our work on the industrial base that supports DOD, having more than one supplier of a critical material is often desirable;[40] however, the lack of coordination between NNSA and DOE on future uranium enrichment

[40]See, for example, GAO, *Defense Industrial Base: Integrating Existing Supplier Data and Addressing Workforce Challenges Could Improve Risk Analysis*, GAO-18-435 (Washington, D.C.: June 13, 2018). GAO recommended that DOD make better use of existing supplier data and identify the appropriate workforce mix needed to work with business-sensitive data. One recommendation has been implemented, while the other has not yet been implemented.

capabilities raises questions about whether the process is being managed from a strategic perspective.

Moreover, DOE's funding of the large centrifuge demonstration project has the potential to undermine the credibility of or prejudice the selection of a future option under NNSA's AOA process. Regardless of DOE's intentions, one part of the agency appears to be committing to the development of a specific technology that it knows could be capable of producing unobligated enriched uranium for NNSA's needs in the future—while another part of the agency continues to study options. By making a commitment to the development of the large centrifuge option, DOE could undermine the deliberative AOA process that NNSA has been pursuing for the past several years to identify a suitable and cost-effective enrichment technology. Notably, if the AOA process results in the selection of the large centrifuge technology, concerns could be raised as to whether that technology was given an unfair advantage through the DOE HALEU demonstration project, to the detriment of other technologies and options under consideration in the AOA process. These concerns could be amplified by the fact that, according to an NNSA official, no clear official U.S. government decision has been made that HALEU fuel for DOD microreactors must be unobligated, raising questions about the urgency of the need to develop a domestic enrichment capability to produce HALEU.

DOE's Guide 413.3-22, *Analysis of Alternatives,* states that it is important that the AOA process and its results are validated by an organization independent of the AOA team and the program office to ensure that a high-quality AOA is developed, presented, and defended to management. Upon completion of an NNSA AOA, the Director of NNSA's Office of Cost Estimating and Program Evaluation must evaluate the AOA for, among other things, completeness, quality, technical soundness, and adherence to the established processes and policies that GAO developed for AOAs.[41] According to NNSA Business Operating Procedure 413.6, an independent review is one of the most reliable means to validate an AOA process. Without an independent review, the results are more likely to include organizational bias or lack the thoroughness needed to ensure that a preferred solution is chosen and not a favored solution.

[41]For established processes and policies for AOAs, see GAO, *Amphibious Combat Vehicle: Some Acquisition Activities Demonstrate Best Practices; Attainment of Amphibious Capability to Be Determined,* GAO-16-22 (Washington, D.C.: Oct. 28, 2015), appendix I.

The Nuclear Fuel Working Group Strategy Identified Additional Mitigation Actions for Risks to the Unobligated Uranium Supply Chain That Are Still Early in Planning

In addition to further discussing a proposed uranium reserve, the Nuclear Fuel Working Group strategy identified additional actions intended to mitigate risks to the uranium supply chain. The strategy addresses general risks to the domestic uranium industry, and several of the proposed actions to mitigate these risks would also address risks specific to the supply chain for unobligated uranium needed for defense purposes. Because these actions were announced in April 2020, they are still early in development, and funding has not yet been requested or provided for them. Examples of actions included in the strategy include the following:

- **Extend the Russian Suspension Agreement.** The strategy supports Commerce's efforts to extend the Russian Suspension Agreement, under which Russia agreed to restrict the volume of its uranium exports to the United States. The strategy states that Russia has become a major enrichment services supplier to U.S. nuclear reactor operators and has aggressively targeted the U.S. uranium market for decades. According to the strategy, the Russian Suspension Agreement may be the sole buffer preventing Russia from "forcing" all enrichment services out of the United States. In October 2020, Commerce announced an extension of the agreement through 2040. The agreement allows Russian uranium exports to meet approximately 17 percent of U.S. enrichment demand over the next 20 years, and will be no higher than 15 percent starting in 2028.
- **Establish a nuclear industrial base advisory committee.** DOD relies on an extensive network of suppliers that make up the defense industrial base, which provides the components, subsystems, raw materials, and equipment needed to develop and sustain DOD's weapon systems,[42] and the Nuclear Fuel Working Group strategy document advocates for the creation of a U.S. "nuclear industrial base" analogous to the DOD industrial base. Specifically, the strategy calls for creation of a nuclear industrial base advisory committee to make recommendations on the intersection between the government and the private sector on domestic uranium issues. In making this recommendation, the strategy states that other nations have

[42]The U.S. defense industrial base is the combination of people, technology, institutions, technological know-how, and facilities used to design, develop, manufacture, and maintain the weapons needed to meet U.S. national security objectives. See GAO-18-435. GAO recommended that DOD make better use of existing supplier data and identify the appropriate workforce mix needed to work with business-sensitive data. One of the two recommendations was closed, while the other remains open.

integrated, whole-of-government approaches that allow their nuclear industries to compete effectively for market share.

Legislation has also been introduced related to the nuclear industrial base. The Senate bill for the fiscal year 2021 National Defense Authorization Act calls for the creation of an ongoing analysis capability within NNSA to monitor the industrial base supporting NNSA's weapons programs.[43] The Senate bill would also amend existing law to make it the policy of the United States that reliance on uranium imports raises significant national security concerns; to revive and strengthen the supply chain for nuclear fuel produced in the United States; and to expand production of nuclear fuel in the United States.[44] The report accompanying the House bill for the fiscal year 2021 National Defense Authorization Act also directs NNSA to provide a plan to monitor its industrial base as it pertains to nuclear weapon components by February 2021.

The Nuclear Fuel Working Group's Strategy Is Missing Some Desirable Characteristics of a National Strategy

The Nuclear Fuel Working Group's strategy is not fully consistent with all of the desirable characteristics of a national strategy that we have identified in previous work.[45] These characteristics include (1) a statement of purpose, scope, and methodology; (2) problem definition and risk assessment; (3) goals, subordinate objectives, activities, and performance measures; (4) resources, investments, and risk management; (5) organizational roles, responsibilities, and coordination; and (6) integration and implementation.

In our analysis of the working group's strategy, we found that it is partially consistent with five desirable characteristics of an effective national strategy and not consistent with one desirable characteristic. Table 2 briefly describes the elements of the desirable characteristics and summarizes our assessment of the extent to which the working group's strategy is consistent with each of the characteristics.

[43]S. 4049, 116th Cong. § 3153 (2020).

[44]S. 4049, 116th Cong. § 3158 (2020).

[45]GAO-04-408T.

Table 2: Assessment of Nuclear Fuel Working Group Strategy Compared with Desirable Characteristics of National Strategies

Desirable characteristic	Extent to which the strategy is consistent
Purpose, scope, and methodology: addresses why the strategy was produced, the scope of its coverage, and the process by which it was developed.	Partially consistent
Problem definition and risk assessment: addresses the particular national problems and threats toward which the strategy is directed.	Partially consistent
Goals, subordinate objectives, activities, and performance measures: addresses what the strategy is trying to achieve; steps to achieve those results; as well as the priorities, milestones, and performance measures to gauge results.	Partially consistent
Resources, investments, and risk management: addresses what the strategy will cost, the sources and types of resources and investments needs, and where resources and investments should be targeted based on balancing risk reduction with costs.	Not consistent
Organizational roles, responsibilities, and coordination: addresses which organizations will implement the strategy, their roles and responsibilities, and mechanisms for coordinating their efforts.	Partially consistent
Integration and implementation: addresses how a national strategy relates to other strategies' goals, objectives, and activities, and to subordinate levels of government and their plans to implement the strategy.	Partially consistent

Legend:

-Consistent: The Nuclear Fuel Working Group Strategy addressed a desirable characteristic without significant gaps in coverage of the elements associated with the characteristic.

-Partially consistent: The Nuclear Fuel Working Group Strategy addressed a desirable characteristic with significant gaps in coverage of the elements associated with the characteristic.

-Not consistent: The Nuclear Fuel Working Group Strategy did not address a desirable characteristic or did not demonstrate coverage of the elements associated with the characteristic.

Sources: GAO analysis of U.S. Department of Energy, "Restoring America's Competitive Nuclear Energy Advantage" (Washington, D.C.: 2020), and GAO, Combating Terrorism: Evaluation of Selected Characteristics in National Strategies Related to Terrorism, GAO-04-408T (Washington, D.C.: Feb. 3, 2004). | GAO-21-28

As shown in the table above, we found that the working group's strategy incorporates some elements of the desirable characteristics of an effective national strategy. However, the strategy also lacks some elements of each characteristic, or has other limitations. Specifically:

Purpose, scope, and methodology. The working group's strategy clearly states its purpose and why it was produced. It also clearly states that the scope of its coverage is to conduct a fuller analysis of national security considerations with respect to the entire nuclear fuel supply chain. However, certain details related to the process by which the strategy was developed are not identified. For example, although the methodology section includes some details, such as the leaders of the effort and some previous efforts, it does not identify how the working group collected and evaluated evidence, analyzed information, or validated findings and recommendations to determine that the proposed recommendations would be effective or the most appropriate actions for addressing identified risks. A complete description of the methodology in a national strategy could make the document more useful to the

organizations responsible for implementing the strategy, as well as to oversight organizations, such as Congress.

Problem definition and risk assessment. The strategy clearly defines the problems facing the U.S. nuclear industry, including a description of the causes and the operating conditions in key sectors of the industry. For example, the strategy identifies several factors that have contributed to the current distressed state of domestic uranium producers, such as declining global demand for uranium for nuclear power and extensive foreign competition. However, elements of risk assessment are not stated in the document and, because the strategy's methodology is limited, as stated above, the extent to which the working group assessed risks in its process of developing the strategy is unclear. For example, the strategy does not provide a statement of the likelihood of the risks facing the U.S. nuclear industry—such as the likelihood that all U.S. uranium mines would cease operations—or an explanation of the impact of those risks on the missions requiring a viable domestic nuclear industry. We have previously reported that assessing risks entails considering both the likelihood of the risk and the impact of the risk on the mission.[46] More specific information on risk assessment would give the implementing agencies better guidance to implement the strategy.

Goals, subordinate objectives, activities, and performance measures. The strategy states its overall goals and subordinate objectives and the activities that will be undertaken to achieve those outcomes. However, some elements of this characteristic are not identified in the strategy. For example, the strategy does not set clear and specific desired performance results, such as reaching specific measures of industrial health. In addition, beyond the immediate goal of supporting the front end of the fuel cycle, the priority of other proposed actions in the strategy is not clearly stated or specified. The strategy also does not identify measures for assessing performance of the proposed actions and how progress toward the strategy's goals and objectives would be tracked. Although the strategy refers to future scenarios that suggest performance monitoring, such as by stating that "other actions will be considered going forward, depending on conditions, needs, and progress," it does not provide further details, such as the monitoring mechanisms that could be used to determine programmatic progress and identify needed improvements. Establishing clear desired results and

[46]GAO, *Enterprise Risk Management: Selected Agencies' Experiences Illustrate Good Practices in Managing Risk*, GAO-17-63 (Washington, D.C.: Dec. 1, 2016). This report does not contain any new recommendations.

performance measures could help provide implementing agencies with an effective way of measuring progress toward the strategy's goals.

Resources, investments, and risk management. The strategy does not provide a cost estimate for the overall implementation of the strategy nor does it define funding needs or cost estimates for its specific proposed objectives or activities not already included in the fiscal year 2021 budget or previously funded. In addition, according to the desirable characteristics, a strategy should ideally give guidance on where necessary resources and investments should be targeted, including guidance to implementing agencies on how to manage their resources and investments. We found that the strategy does not include details, such as the level of agency resources and investments needed to support proposed actions and, as a result, it is not clear how proposed actions will be funded and sustained in the future. DOE officials stated in July 2020 that the strategy does not provide cost estimates beyond fiscal year 2021 because there is so much uncertainty about future costs, which will depend on timing, market conditions, and performance of other linked activities. Additionally, although the purpose of the strategy is to manage the risks to the uranium industry, the strategy does not include information on risk management.[47] However, because the strategy does not identify measures for how the performance of the proposed actions would be assessed, as described above, it is unclear how or whether agencies will implement risk management strategies as they take action. More guidance on resources, investments, and risk management would help implementing agencies allocate resources and investments according to priorities and constraints, track costs and performance, and shift such investments and resources, as appropriate.

Organizational roles, responsibilities, and coordination. The strategy identifies the roles and responsibilities of agencies in implementing some of the proposed actions, but it does not identify responsible agencies for most of the recommended actions. For example, while the strategy recommends establishing a nuclear industrial base advisory committee charged with making recommendations on nuclear supplier base

[47]We have previously reported on a risk management framework based on industry best practices and other criteria. Leading practices identified in this framework include establishing internal controls and performance measurement guidelines for responses to risks. See GAO, *Risk Management: Further Refinements Needed to Assess Risks and Prioritize Protective Measures at Ports and Other Critical Infrastructure*, GAO-06-91 (Washington, D.C.: Dec. 15, 2005). GAO made recommendations aimed at helping three Department of Homeland Security components face their next risk management challenges. All recommendations were implemented.

challenges, it does not identify which agencies or offices would make up the advisory committee, or which entity is to lead the committee. In addition to identifying responsible agencies, a strategy could identify specific processes for coordination and collaboration between agencies and organizations that have roles and responsibilities for the strategy. However, we found that the document does not specify mechanisms, tools, or processes for coordinating implementation of the strategy among various agencies. Information about organizational roles, responsibilities, and coordination would be useful to agencies and other stakeholders in fostering coordination and clarifying specific roles, particularly where there is overlap, and thus enhancing both implementation and accountability.

Integration and implementation. The strategy addresses how it complements ongoing missions and activities. For example, the strategy discusses the importance of a viable nuclear industry to ongoing agency missions and activities, such as NNSA's mission to provide LEU and HEU for defense purposes and DOD's development of an advanced deployable microreactor. The strategy also states that it is built upon ongoing work by the National Economic Council, the National Security Council, the Office of Science and Technology Policy, and other federal agencies, but it does not reference the specific work, making it difficult to understand the relationship between the strategy and other strategies or efforts. In addition, the strategy does not include implementation guidelines or mechanisms for proposed actions that were not already ongoing. The strategy does address some basic guidelines for the implementation of the uranium reserve that DOE has proposed, as we have previously described. However, for other proposed actions, the strategy does not identify which agencies will implement the actions, their implementing roles, or coordinating mechanisms for interagency implementation actions. More information on this characteristic would further clarify the relationships among various implementing parties. This, in turn, would foster effective implementation and accountability.

Although the working group's strategy was developed in response to risks and challenges that are ongoing, staff from the National Security Council—which co-chaired the Nuclear Fuel Working Group—told us in June 2020 that the working group would not serve as a coordinating mechanism to guide implementation of the strategy going forward. According to National Security Council staff, the executive agencies that participated in the working group are now responsible for implementation. National Security Council staff stated that DOE, as the agency that published the strategy, would serve as the lead agency to determine roles

and responsibilities going forward and could lead the interagency coordination effort to implement the strategy. In July 2020, DOE officials confirmed that DOE would be the lead agency to coordinate implementation of the strategy and stated that they were in the process of developing an implementation plan.[48] DOE officials said they expected to complete the implementation plan by the end of fiscal year 2020.

Given the ongoing development of DOE's implementation plan, we were unable to verify the extent to which it may address elements that were not contained in the working group strategy. In a written response, however, DOE indicated that it expects the plan to include a section identifying priority actions, metrics of success, overall risk identification and management, and the organization of tasks by department and agency, including a table designating the office of primary responsibility for each action. Our previous work on interagency collaborative mechanisms and key collaboration practices has found that it is important to ensure that the relevant participants have been included in the collaborative effort and that collaborating agencies need to establish mutually reinforcing or joint strategies.[49] DOE's response also indicated that it expects each department and agency will develop a unique implementation plan specific to its identified tasks. The plans are to be appended to the working group's strategy document as they are developed and approved within each organization.

However, DOE's written response did not identify certain elements that we found were missing in the working group strategy, such as a time line for agency actions or a description of the cost estimates or funding needed to implement the strategy. By more fully addressing each of the desirable characteristics of a national strategy in its implementation plan, DOE could improve implementation of the strategy, help ensure the

[48]In November 2020, DOE revised its position and stated that DOE would be willing to lead coordination of strategy implementation "if the White House requested." DOE also stated that the White House is also considering reconvening the Nuclear Fuel Working Group as a coordinating mechanism. Furthermore, DOE stated that it is working on two implementation plans, a DOE-specific plan and a draft integrated Nuclear Fuel Working Group plan.

[49]See GAO, *Managing for Results: Key Considerations for Implementing Interagency Collaborative Mechanisms,* GAO-12-1022 (Washington, D.C.: Sept. 27, 2012); and *Results-Oriented Government: Practices That Can Help Enhance and Sustain Collaboration among Federal Agencies*, GAO-06-15 (Washington, D.C.: Oct. 21, 2005). GAO-12-1022 did not contain recommendations. In GAO-06-15, GAO recommended that the Director of the Office of Management and Budget focus on additional programs in need of collaboration and promote the practices in the report. The recommendation was implemented.

usefulness of the strategy in resource and policy decisions, and better ensure accountability going forward.

Conclusions

Since 2013, our nation has relied on a finite and diminishing inventory of unobligated uranium to meet national security and defense needs, including production of tritium for the nuclear weapons stockpile. NNSA is currently evaluating options for a future domestic enrichment capability. However, agency officials and nuclear industry representatives have raised concerns that other sectors of the unobligated uranium supply chain—such as the domestic uranium mining and uranium conversion sectors—may face significant long-term risks from foreign competition and uncertainty over the demand for uranium.

The uranium reserve that DOE proposed in the fiscal year 2021 budget justification and that is addressed in the Nuclear Fuel Working Group's strategy is intended to ensure a guaranteed near-term demand for uranium and help revitalize the domestic industry, allowing time for industry conditions to improve. However, it is unclear how the funding needs for the reserve were determined. As DOE moves forward with establishing the reserve, documenting the basis for its cost estimate could provide assurance that DOE's funding requests to the Congress for the reserve are reasonable.

DOE and NNSA have taken separate steps to mitigate risks to the domestic enrichment sector, which is also vital in guaranteeing a long-term supply of unobligated uranium for defense purposes. However, these efforts are not fully coordinated. Regardless of whether NNSA's AOA for domestic uranium enrichment results in selection of the large centrifuge option being developed by Centrus or the small centrifuge option being developed by Oak Ridge National Laboratory, NNSA will need to ensure that its AOA process was unbiased. Specifically, if NNSA selects the small centrifuge, different parts of DOE—NNSA and DOE-NE—would be separately funding different domestic enrichment capabilities, raising questions about whether this investment in multiple suppliers was decided strategically. Alternatively, if NNSA selects the large centrifuge as its preferred option for meeting its future enrichment needs, there could be questions as to whether the DOE-NE support for the large centrifuge program influenced the outcome of the AOA process. A thorough review of the AOA by NNSA's independent Office of Cost Estimating and Program Evaluation, as required under an NNSA Business Operating Procedure, would instill credibility in the AOA process and ensure it is unbiased toward any solution.

Finally, the Nuclear Fuel Working Group strategy identified actions to support and revitalize the domestic nuclear industry, including some actions that may benefit the unobligated uranium supply chain. However, the strategy lacks certain elements and therefore does not meet or only partially meets the desirable characteristics of national strategies we have identified in previous work. As the lead agency for implementation of the strategy, DOE has an opportunity to address and clarify these missing elements in the implementation plan it is developing for the strategy. By doing so, DOE could improve implementation of the strategy, help ensure the strategy's usefulness in resource and policy decisions, and better ensure accountability going forward.

Recommendations for Executive Action

We are making a total of three recommendations, two to the Secretary of Energy and one to the Director of NNSA's Office of Cost Estimating and Program Evaluation:

The Secretary of Energy should ensure, particularly as operational details for the uranium reserve are clarified, that any future funding requests for the uranium reserve are based on cost estimates that have been thoroughly reviewed and deemed reasonable. (Recommendation 1)

The Director of NNSA's Office of Cost Estimating and Program Evaluation should, during the office's required review of NNSA's analysis of alternatives (AOA) for a capability to meet NNSA's future unobligated enriched uranium needs, ensure that the AOA was unbiased toward any solution. (Recommendation 2)

The Secretary of Energy should ensure that the implementation plan under development for *Restoring America's Competitive Nuclear Energy Advantage: a Strategy to Assure U.S. National Security* fully addresses each of the desirable characteristics GAO has identified for a national strategy. (Recommendation 3)

Agency Comments and Our Evaluation

We provided a draft of this report to the Secretaries of Energy, Defense, State, and Commerce; the Administrator of the National Nuclear Security Administration; the Chairman of the Nuclear Regulatory Commission; the Assistant to the President for National Security Affairs; and the Vice President for Government Relations of the Tennessee Valley Authority for review and comment. We also provided a technical statement of facts to ConverDyn. Neither DOD, the National Security Council, nor State provided comments. Commerce, NRC, and TVA provided technical comments, which we incorporated as appropriate. DOE provided written

comments and technical comments on its and NNSA's behalf. In DOE's written comments, which are reproduced in Appendix I, the agency concurred with our recommendations, and described actions it is taking or considering.

In its technical comments, which we also incorporated as appropriate, DOE provided additional information related to two of our findings.

First, DOE provided new data in its technical comments regarding the formulation of its cost estimate for the proposed uranium reserve. DOE officials did not disclose the existence of this data to us during our audit work, including in our meetings with DOE officials in March 2020 and July 2020 during which we discussed the basis for the reserve's cost estimate. In its technical comments, DOE stated it was unable to provide this information to us during our audit work because of the pre-decisional nature of the data.[50] However, DOE's fiscal year 2021 budget justification was released in February 2020 and included the $150 million request. Accordingly, it is unclear why DOE considered the data to be pre-decisional during our meetings in March and July. Because DOE provided this information to us at the conclusion of our review, we were unable to fully assess the validity of the underlying data or determine whether it provides a reasonable basis for the agency's uranium reserve cost estimate. We note that the data provided consists of one page with three cost scenarios that are identical except for the uranium and enrichment prices used in each scenario. The document does not provide information likely needed to evaluate the cost estimate, such as the basis for the amount of uranium required to be in the reserve (which is also identical in all three scenarios).

Second, in both its technical and written comments, DOE stated that it is willing to lead coordination of the integrated implementation plan for the Nuclear Fuel Working Group strategy if the White House requested that DOE do so. This appears to be a change in the department's position—in July 2020, DOE officials told us that DOE would lead interagency coordination for implementing the strategy. DOE's statement in its comments is also not consistent with statements made to us by National Security Council officials in June 2020 that DOE would be the lead agency on behalf of the administration to coordinate interagency implementation of the strategy. As noted above, the National Security Council did not provide comments on a draft of this report. However, the

[50]The draft or pre-decisional nature of an agency document does not automatically block GAO's right of access to it. 31 U.S.C. § 716.

apparent DOE position change raises further questions about the federal government's commitment to implementing the working group's strategy and achieving the strategy's ambitious goals.

We are sending copies of this report to the appropriate congressional committees; the Secretaries of Energy, Defense, State, and Commerce; the Administrator of the National Nuclear Security Administration; the Chairman of the Nuclear Regulatory Commission; the Assistant to the President for National Security Affairs; and the Vice President for Government Relations of the Tennessee Valley Authority; and other interested parties. In addition, this report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or bawdena@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made significant contributions to this report are listed in appendix II.

Allison Bawden
Director, Natural Resources and Environment

List of Committees

The Honorable James M. Inhofe
Chairman
The Honorable Jack Reed
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Lamar Alexander
Chairman
The Honorable Dianne Feinstein
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Adam Smith
Chairman
The Honorable Mac Thornberry
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Marcy Kaptur
Chairwoman
The Honorable Mike Simpson
Ranking Member
Subcommittee on Energy and Water Development,
and Related Agencies
Committee on Appropriations
House of Representatives

Appendix I: Comments from the Department of Energy

Department of Energy
Washington, DC 20585

November 16, 2020

Ms. Allison Bawden
Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street N.W.
Washington, DC 20548

Dear Ms. Bawden:

The Department of Energy (DOE) appreciates the opportunity to comment on the Government Accountability Office's (GAO) draft report titled, "*Uranium Management: Actions to Mitigate Risks to Domestic Supply Chain Could be Better Planned and Coordinated* (GAO-21-28)".

The draft report contained three recommendations, of which GAO directed two recommendations to the Secretary of Energy and one recommendation to the Director of Cost Estimating and Program Evaluation for the National Nuclear Security Administration (NNSA). DOE concurs with GAO's recommendations.

The Department will base future funding requests for the uranium reserve on cost estimates that have been thoroughly reviewed and deemed reasonable and will make certain that the DOE Implementation Plan under development for *Restoring America's Competitive Nuclear Advantage: A Strategy to Assure U.S. National Security* fully addresses each of the desirable characteristics that GAO has identified for a national strategy. NNSA's Office of Cost Estimating and Program Evaluation will use sound analytical rigor using GAO's Analysis of Alternatives Best Practices for the preferred solution.

DOE's more detailed responses to the recommendations and technical comments are enclosed. GAO should direct any questions to Ms. Kelly Scott, within the Office of Nuclear Energy, at 202-586-4288.

Sincerely,

Dr. Rita Baranwal
Assistant Secretary for Nuclear Energy

Enclosure

Enclosure

Management Response
GAO Draft Report: *Uranium Management: Actions to Mitigate Risks to Domestic Supply Chain Could be Better Planned and Coordinated* (GAO-21-28)

Recommendation #1: The Secretary of Energy should ensure, particularly as operational details for the uranium reserve are clarified, that any future funding requests for the uranium reserve are based on cost estimates that have been thoroughly reviewed and deemed reasonable.

DOE Response: Concur

The Secretary of Energy will base future funding requests for the uranium reserve on cost estimates that have been thoroughly reviewed and deemed reasonable. The Department will prepare the President's Fiscal Year 2022 Budget Request and any future funding requests consistent with this recommendation.

Estimated Completion Date: When the President's FY 2022 budget is submitted to Congress

Recommendation #2: The Director of NNSA's Office of Cost Estimating and Program Evaluation should, during the office's required review of NNSA's analysis of alternatives (AOA) for a capability to meet NNSA's future unobligated enriched uranium needs, ensure that the AOA was unbiased toward any solution.

NNSA Response: Concur

NNSA's Office of Cost Estimating and Program Evaluation (CEPE) will use sound analytical rigor following GAO's AOA Best Practices for the preferred solution. CEPE will conduct a review to assess reasonableness of cost estimates, schedule analysis and technical soundness one month after the completion of the AOA.

Estimated Completion Date: One month after the completion of the AOA

Recommendation #3: The Secretary of Energy should ensure that the implementation plan under development for *Restoring America's Competitive Nuclear Energy Advantage: a Strategy to Assure U.S. National Security* fully addresses each of the desirable characteristics GAO has identified for a national strategy.

DOE Response: Concur

DOE is currently working on two detailed implementation plans for *Restoring America's Competitive Nuclear Energy Advantage: a Strategy to Assure U.S. National Security*: (1) a DOE-specific implementation plan for DOE-led actions in support of the Strategy, and (2) a draft

integrated Nuclear Fuel Working Group (NFWG) Implementation Plan for consideration by the interagency and the White House.

The DOE Implementation Plan will address each of the desirable characteristics that GAO has identified. The draft integrated NFWG Implementation Plan will also include the stated desirable characteristics or contain guidance for Departments and Agencies to include them in their corresponding implementation plans, as appropriate. DOE is willing to lead coordination of integrated Strategy implementation if requested by the White House. DOE does not have the authority to direct how, when, or if other Departments and Agencies implement the Strategy.

Estimated Completion Date: The DOE Implementation Plan is estimated to be approved by December 2020. On October 27, 2020, DOE submitted the draft integrated NFWG Implementation Plan to the interagency and the White House for consideration.

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

Allison Bawden at (202) 512-3841 or bawdena@gao.gov

Staff Acknowledgments

In addition to the contact named above, William Hoehn, (Assistant Director), Bridget Grimes (Analyst in Charge), Eric Bachhuber, Antoinette Capaccio, Pamela Davidson, Ellen Fried, Lauren Gomez, Cami Pease, Katrina Pekar-Carpenter, Stephen Sanford, Sara Sullivan, Sarah Veale, and Karen Villafana made contributions to this report.