United States Government Accountability Office

Report to Congressional Committees

July 2022

# NUCLEAR WASTE CLEANUP

# DOE's Efforts to Manage Depleted Uranium Would Benefit from Clearer Legal Authorities

**Accessible Version**

GAO-22-105471

# GAO Highlight

Highlights of GAO-22-105471, a report to congressional committees.

July 2022

# NUCLEAR WASTE CLEANUP

## DOE's Efforts to Manage Depleted Uranium Would Benefit from Clearer Legal Authorities

## Why GAO Did This Study

EM is responsible for cleaning up the nuclear waste left behind at two former federal uranium enrichment sites (Portsmouth, in Ohio, and Paducah, in Kentucky). One of the cleanup-related activities is the conversion of DUF6—a highly corrosive by-product of the uranium enrichment process that can be dangerous to human health and the environment—into depleted uranium oxide. This is a more stable chemical form of depleted uranium that can be disposed of or reused. The conversion facilities began operating at Portsmouth in 2010 and Paducah in 2011, but both facilities stopped conversion operations in March 2020 because of the COVID-19 pandemic.

Senate Report 117-39 accompanying S. 2792, a bill for the National Defense Authorization Act for Fiscal Year 2022, included a provision for GAO to review the two conversion facilities. This report examines (1) EM's response to the facilities' COVID-19 shutdown and effects on the facilities' cost and schedule estimates, (2) EM's agreements to provide DUF6 to other entities, and (3) EM's plans for depleted uranium oxide and hydrofluoric acid.

GAO reviewed project documentation, transfer and sales agreements, and legislation; and interviewed EM and National Nuclear Security Administration officials, state regulators, and representatives for the disposal facilities.

## What GAO Recommends

Congress should consider clarifying DOE's authority to sell depleted uranium, as well as any conditions connected to such sales. DOE did not comment on this report.

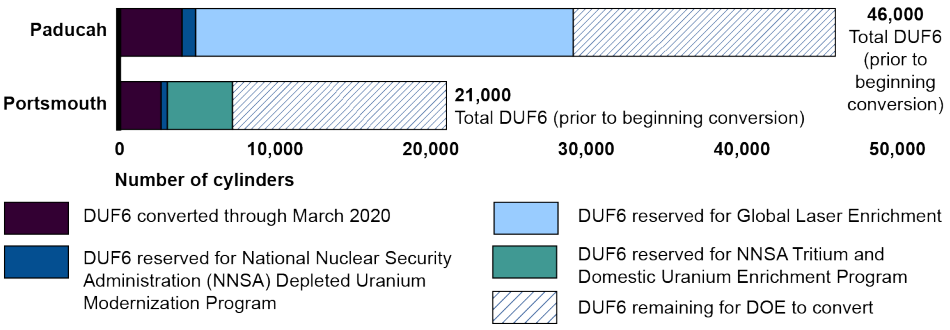
View GAO-22-105471. For more information, contact Nathan Anderson at (202) 512-3841 or andersonn@gao.gov.

## What GAO Found

The Department of Energy's (DOE) Office of Environmental Management (EM) used the COVID-19 shutdown to perform maintenance and modifications at the two depleted uranium hexafluoride (DUF6) conversion facilities located at the Portsmouth and Paducah sites. These facilities convert DUF6 into two primary products: depleted uranium oxide and hydrofluoric acid. According to EM, the agency spent about $47.4 million on modifications that officials say will improve the facilities' efficiency. EM has not fully assessed the impact of this shutdown on the conversion mission, but officials said that they were developing new cost and schedule estimates for the facilities that will be finalized in 2022. Conversion operations restarted at the Paducah facility in November 2021, and EM officials told us operations restarted at the Portsmouth facility in July 2022.

EM has three agreements to reserve nearly 30,000 cylinders of DUF6 (about 44 percent of the inventory) for use by other entities. If the agreements are finalized, the agency may not need to convert all its DUF6 and could reduce operations of the conversion facilities by roughly 30 years, potentially saving over $2 billion in operations costs. EM has two agreements to transfer ownership of nearly 5,500 cylinders to the National Nuclear Security Administration for two separate programs, but the plans and timing of one agreement are uncertain. EM has also reserved over 24,000 cylinders to sell to a private company. However, DOE's authority to sell depleted uranium is doubtful, as it appears to be inconsistent with the 1996 legislation governing DOE uranium disposition. Clarifying DOE's authority to sell depleted uranium could help avoid litigation that could interrupt DOE's efforts to sell DUF6.

**Breakdown of DOE's Depleted Uranium Hexafluoride (DUF6) Inventory**




Source: GAO analysis of Department of Energy (DOE) documentation. | GAO-22-105471

**Accessible Data Table for Highlight Figure**

| | # of cylinders @ the Paducah site | # of cylinders @ the Portsmouth site |
|---|---|---|
| Total DUF6 (prior to beginning conversion) | 46,000 | 21,000 |
| DUF6 converted through March 2020 | 4,006 | 2,663 |
| DUF6 reserved for NNSA Depleted Uranium Modernization Program | 873 | 396 |
| DUF6 reserved for NNSA Tritium and Domestic Uranium Enrichment Program | 0 | 4,198 |
| DUF6 reserved for Global Laser Enrichment | 24,275 | 0 |
| DUF6 remaining for DOE to convert | 16846 | 13743 |

EM has identified options for disposing of depleted uranium oxide, but plans have not been finalized. EM has determined that three waste disposal sites may be suitable for the depleted uranium oxide but, as of March 2022, only one site is licensed to receive it. Officials said that the agency has been waiting for funding to begin the disposal process. In addition, EM has directed its contractor to sell hydrofluoric acid to a private company and apply the proceeds of those sales to contract costs. EM has been able to keep and use the proceeds of the hydrofluoric acid sales under appropriations laws enacted from fiscal years 2011 through 2022.

# Contents

**Abbreviations**

| | |
|---|---|
| DOE | Department of Energy |
| DU | depleted uranium |
| DU metal | depleted uranium metal |
| DU oxide | depleted uranium oxide |
| DUF6 | depleted uranium hexafluoride |
| DUF4 | depleted uranium tetrafluoride |
| EM | Office of Environmental Management |
| GLE | Global Laser Enrichment |
| MCS | Mid-America Conversion Services, LLC |
| NNSA | National Nuclear Security Administration |
| NNSS | Nevada National Security Site |
| ORNL | Oak Ridge National Laboratory |
| PPPO | Portsmouth/Paducah Project Office |
| WCS | Waste Control Specialists |
| Y-12 | Y-12 National Security Complex |

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Congressional Committees

Enriched uranium is a critical component in nuclear weapons and energy, but the enrichment process creates radioactive and hazardous by-products that often must be treated and disposed of as waste. One of those by-products—depleted uranium hexafluoride (DUF6)—has historically been considered waste because the process required to extract the remaining useful quantities of uranium-235 after the initial enrichment process is complex and can be costly.[1] In addition, because DUF6 can be dangerous to human health and the environment as it can form extremely corrosive and potentially lethal compounds, the waste must be safely managed.[2]

The federal government's inventory of DUF6 is stored in large steel containers, called cylinders, that contain approximately 10 to 13 tons of material at two Department of Energy (DOE) sites—the Portsmouth site in Piketon, Ohio, and the Paducah site near Paducah, Kentucky. The federal government previously enriched uranium at these sites, and both sites are now undergoing nuclear waste cleanup activities led by DOE's Office of Environmental Management (EM). In 2002, EM issued a contract for design, construction, and initial operation of two facilities—one at the Portsmouth site and one at the Paducah site—to convert DUF6 to depleted uranium oxide (DU oxide), a more stable chemical form of depleted uranium that can be reused or disposed of.[3] The Portsmouth conversion facility began operating in 2010 and the Paducah facility in

[1]Enriching uranium increases the concentration of uranium-235, which is necessary for use in nuclear weapons or reactors. 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 a different number of neutrons.

[2]Uranium enrichment involves combining uranium with the chemical fluorine to form uranium hexafluoride. When uranium hexafluoride reacts with water, it can burn the skin, eyes, and internal organs.

[3]Depleted uranium is a by-product of the uranium enrichment process after a significant fraction of fissile material—uranium-235—has been removed from natural uranium. There are several forms of depleted uranium, including DUF6 and DU oxide. DUF6 is the type of depleted uranium that initially results from the enrichment process; however, DUF6 can be further converted into other forms of depleted uranium, depending on need. See app. I for a description of some forms of depleted uranium.

2011, but several safety and reliability issues during early operations at the Portsmouth facility resulted in a shutdown of both facilities in 2015. Both facilities restarted by January 2018 after a new contractor—Mid-America Conversion Services, LLC (MCS)—improved safety at the sites.

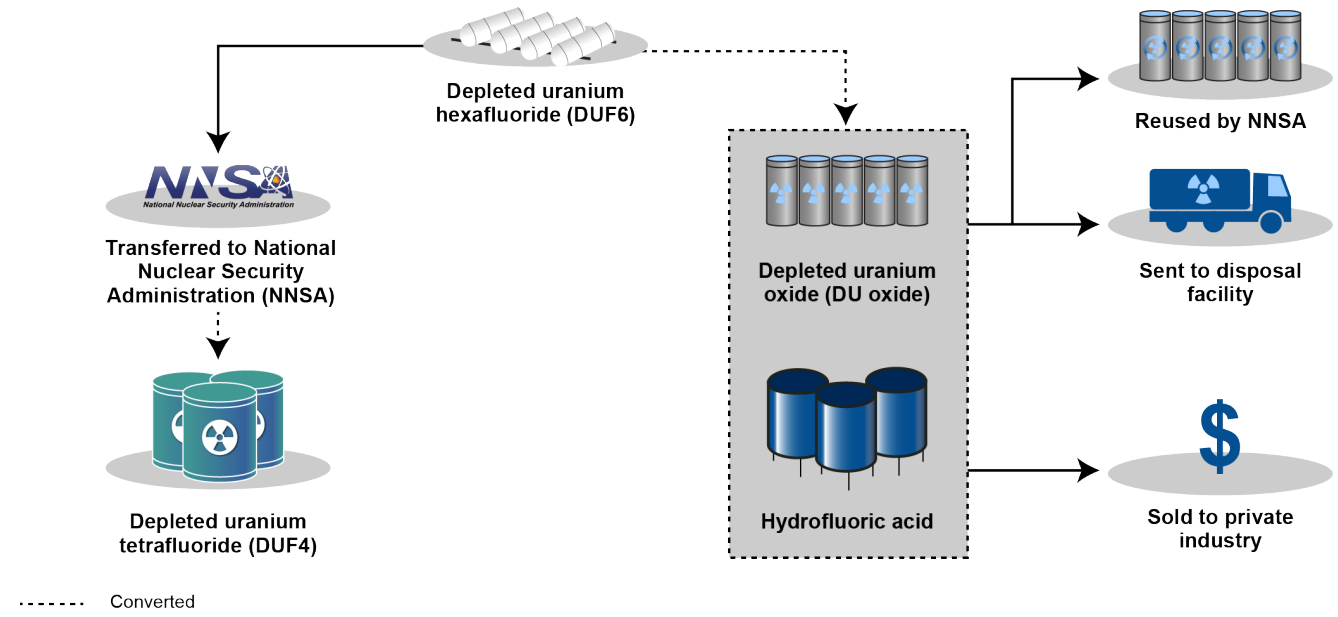
The conversion operations at both sites stopped again in March 2020 because of the COVID-19 pandemic. Up until the March 2020 shutdown, EM had converted about 6,640 cylinders of DUF6 waste out of a total inventory of about 67,000 cylinders.

The National Nuclear Security Administration (NNSA) has identified a use for DUF6 that will help EM reduce the inventory of DUF6 cylinders. NNSA plans to obtain DUF6 from EM and convert it into depleted uranium tetrafluoride (DUF4) for use in nuclear weapons components. In September 2018, NNSA and EM agreed to install equipment at the Portsmouth facility to convert approximately 1,200 cylinders of DUF6 into DUF4.

The DUF6 conversion process results in two primary products—DU oxide and hydrofluoric acid—and EM has to determine how to manage these products.[4] According to officials, EM is working with NNSA to explore options for reuse of some DU oxide. DU oxide that cannot be reused by NNSA will be disposed of at an appropriate waste disposal facility. In 2004, EM decided that it would sell hydrofluoric acid. See figure 1 below for a depiction of some different ways EM could manage its DUF6 inventory.

[4]Other products that EM has to dispose of include calcium fluoride and excess cylinders that previously contained DUF6.

**Figure 1: Potential Pathways for DOE's DUF6 Inventory**




Source: GAO analysis of Department of Energy (DOE) documentation. | GAO-22-105471

Senate Report 117-39 accompanying S. 2792, a bill for the National Defense Authorization Act for Fiscal Year 2022, included a provision for us to review the performance of the DUF6 conversion facilities and DOE's plans to dispose of DU oxide and hydrofluoric acid. This report examines (1) EM's response to the conversion facilities' COVID-19 shutdown and effects on the facilities' cost and schedule estimates, (2) EM's agreements to provide DUF6 to other entities, and (3) EM's plans for DU oxide and hydrofluoric acid.

To examine EM's response to the conversion facilities' COVID-19 shutdown and effects on the facilities' cost and schedule estimates, we reviewed relevant documents and data and interviewed agency officials. Specifically, we reviewed the facilities' fiscal year 2021 cost and schedule estimates to understand how long EM currently plans to operate the facilities. We also reviewed DOE and EM COVID-19 operations guidance to be able to describe the changing work conditions during the COVID-19 pandemic and documentation related to restarting the facilities to be able to describe how and when each facility would be able to restart conversion operations. Further, we reviewed cost data from EM's contractor's accounting system to learn how the contractor spent funds

during the shutdown, from April 2020 through November 2021.[5] We determined the data were sufficiently reliable for our purposes based on information that EM officials provided about how the data are collected, maintained, and used. In addition, we interviewed officials with the agency's Portsmouth/Paducah Project Office (PPPO)—the office that manages the two facilities—about the activities undertaken during the shutdown and their efforts to update the facilities' cost and schedule estimates.

To examine EM's agreements to provide DUF6 to other entities, we reviewed documentation related to the agreements and interviewed agency officials and company representatives. Specifically, we reviewed memorandums of agreement that EM has with NNSA and a sales agreement that EM has with Global Laser Enrichment (GLE)—a private company that plans to enrich DUF6 to natural uranium levels—to understand the amount of DUF6 reserved and conditions for each agreement.[6] Further, we reviewed legislation regarding the sale of uranium to better understand what forms of uranium are covered by legislation, as well as the required conditions related to the sale of uranium. We also interviewed EM and NNSA officials and GLE representatives about the status of their agreements, including the progress being made to meet timelines in their agreements.

To examine EM's plans for DU oxide and hydrofluoric acid, we reviewed documentation related to disposal and interviewed EM officials, state regulators, and disposal facility representatives. Specifically, we reviewed EM's environmental impact statement and record of decision for disposition of DU oxide to learn about the options that EM considered for

[5]Both facilities ceased conversion operations in late March 2020 because of the COVID-19 pandemic. We did not include March 2020 costs in our review of cost data, as many costs that month were attributed to normal operations. We reviewed costs through November 2021 because the Paducah facility resumed operations at the end of that month, and EM officials told us that following November 2021, they no longer attributed the continued shutdown of the Portsmouth facility to the COVID-19 pandemic.

[6]GLE plans to build a facility at the Paducah site, where it will use laser-based enrichment technology to reenrich DUF6 to natural uranium hexafluoride, which GLE would then sell in the global market.

disposing of DU oxide.[7] We also reviewed EM's contract for the conversion facilities and the sales agreements between the contractors and a private company to sell hydrofluoric acid to better understand the conditions for sales of hydrofluoric acid. Further, we reviewed legislation regarding the use of sales proceeds of government assets to better understand when and how agencies are allowed to keep and use the proceeds of sales.

In addition, we reviewed hydrofluoric acid sales data that EM's contractor collects in both Excel documents and its accounting system to be able to describe the amount of hydrofluoric acid sold and proceeds of those sales from the first year of sales in 2011 through 2021, the last full year of sales data available. We determined that the data were sufficiently reliable for our purposes based on information that EM officials provided about how the data are collected, maintained, and used. We interviewed EM officials about their work with NNSA concerning reuse of DU oxide and about EM's plans to dispose of DU oxide and other conversion products. We also interviewed representatives for the disposal facilities and Utah and Texas State regulators about their perspectives on receiving DU oxide waste.[8] In addition, we interviewed Ohio State regulators about their perspective on DU oxide being stored at the Portsmouth site.[9]

We conducted this performance audit from October 2021 to July 2022 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

[7]Department of Energy Office of Environmental Management, *Final Supplemental Environmental Impact Statement for Disposition of Depleted Uranium Oxide Conversion Product Generated from DOE's Inventory of Depleted Uranium Hexafluoride*, DOE/EIS-0359-S1 and DOE/EIS-0360-S1 (Washington, D.C.: April 2020); and Record of Decision for Disposition of Depleted Uranium Oxide Conversion Product Generated From Department of Energy's Inventory of Depleted Uranium Hexafluoride, 85 Fed. Reg. 34,610 (June 5, 2020).

[8]We reached out to Nevada State regulators, but they declined to meet with us because they told us that their views were covered by the written comments that they provided on DOE's documentation related to waste disposal at the Nevada disposal site. Nevada officials did not clarify to which documentation they were referring.

[9]We reached out to Kentucky State regulators, but they declined to meet with us because they told us that they have no opinion on the progress being made in DUF6 conversion operations.

the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

# Background

## History of the DUF6 Conversion Facilities

Beginning in the 1940s, the federal government enriched uranium for both national security and civilian purposes. DOE and its predecessor agencies conducted enrichment at three locations: (1) the Paducah site in Kentucky; (2) the Portsmouth site in Ohio; and (3) the East Tennessee Technology Park in Oak Ridge, Tennessee. One of the by-products of the enrichment process was a form of depleted uranium called DUF6, also known as "tails."[10] The DUF6 was placed in large steel cylinders for storage on-site; the cylinders at Oak Ridge were later transferred to Portsmouth.

In 1994, DOE began exploring options to manage its DUF6 inventory. The agency considered several options, including storing the DUF6 cylinders at their original sites and using different technologies to convert DUF6, which becomes highly corrosive when exposed to moisture, into a more stable chemical form of depleted uranium for use or disposal.[11] In 1999, DOE issued a record of decision to convert the DUF6 inventory into the more stable form of DU oxide that can be more easily reused or disposed of.[12]

Around the same time it issued its 1999 record of decision, DOE began requesting proposals to design, construct, and operate DUF6 conversion facilities at the Paducah and Portsmouth sites. In August 2002, the President signed a law requiring that DOE award a contract for

[10]Uranium is categorized by the concentration of uranium-235, expressed as a percentage "assay." Natural uranium has an assay of about 0.7 percent uranium-235. DUF6 is considered depleted uranium because the material is depleted in uranium-235 compared with natural uranium. DOE's DUF6 assay levels range from less than 0.15 percent to about 0.66 percent uranium-235.

[11]DUF6 can be placed into long-term storage, requiring routine monitoring and maintenance activities, but cannot be disposed of. A more stable chemical form of depleted uranium can be disposed of, which is considered to be permanent.

[12]Record of Decision for Long-Term Management and Use of Depleted Uranium Hexafluoride, 64 Fed. Reg. 43,358 (Aug. 10, 1999).

construction and operation of the two DUF6 facilities within 30 days after enactment of the law; EM issued a contract by the end of that month.[13]

## Conversion Facility Roles and Responsibilities

According to EM officials, three primary entities have roles and responsibilities at the DUF6 conversion facilities:

- **EM.** As the DOE office responsible for nuclear waste cleanup, EM is in charge of the overall cleanup activities at the Portsmouth and Paducah sites. As part of this responsibility, the EM headquarters office provides independent oversight of PPPO and the conversion facilities at both sites. EM headquarters provides support in areas including budget planning and execution, contracting and procurement activities, life cycle cost estimates, and annual auditing.
- **PPPO.** PPPO is the field office within EM that manages cleanup efforts at both sites. PPPO is responsible for direct oversight of the contractor that runs the facilities. This includes oversight of all conversion operations in order to ensure that the work that the contractor carries out is performed safely and in compliance with federal, state, and local requirements.
- **MCS.** As the contractor for both conversion facilities, MCS has been responsible for the day-to-day work at the facilities since 2017. MCS provides all personnel, equipment, material, supplies, and services necessary to operate the conversion facilities.

## Conversion Operations

DUF6 conversion operations began at the Portsmouth facility in 2010 and at Paducah in 2011. At the beginning of conversion operations, Paducah had approximately 46,000 DUF6 cylinders and Portsmouth approximately

[13]2002 Supplemental Appropriations Act for Further Recovery From and Response to Terrorist Attacks on the United States, Pub. L. No. 107-206, § 502, 116 Stat. 820, 851 (amending Pub. L. No. 105-204, § 1, 112 Stat. 681, 681 (1998). Requirements in the 2002 law also included that the contract require groundbreaking for construction to occur no later than July 31, 2004; that the contract require construction to proceed expeditiously thereafter; that the contract include as an item of performance the transportation, conversion, and disposition of depleted uranium contained in cylinders located at Oak Ridge; and that no later than 5 days after the date of groundbreaking for each facility, the Secretary of Energy submit to Congress a certification that groundbreaking had occurred.

21,000 DUF6 cylinders—including the inventory originally at Oak Ridge—for a total of about 67,000 cylinders (see fig. 2).

**Figure 2: DUF6 Storage Cylinders at DOE's Portsmouth (Ohio) DUF6 Conversion Facility**

Cylinders containing depleted uranium hexafluoride (DUF6) are stored outdoors on concrete or gravel yards. Each cylinder contains 10 to 13 tons of DUF6.

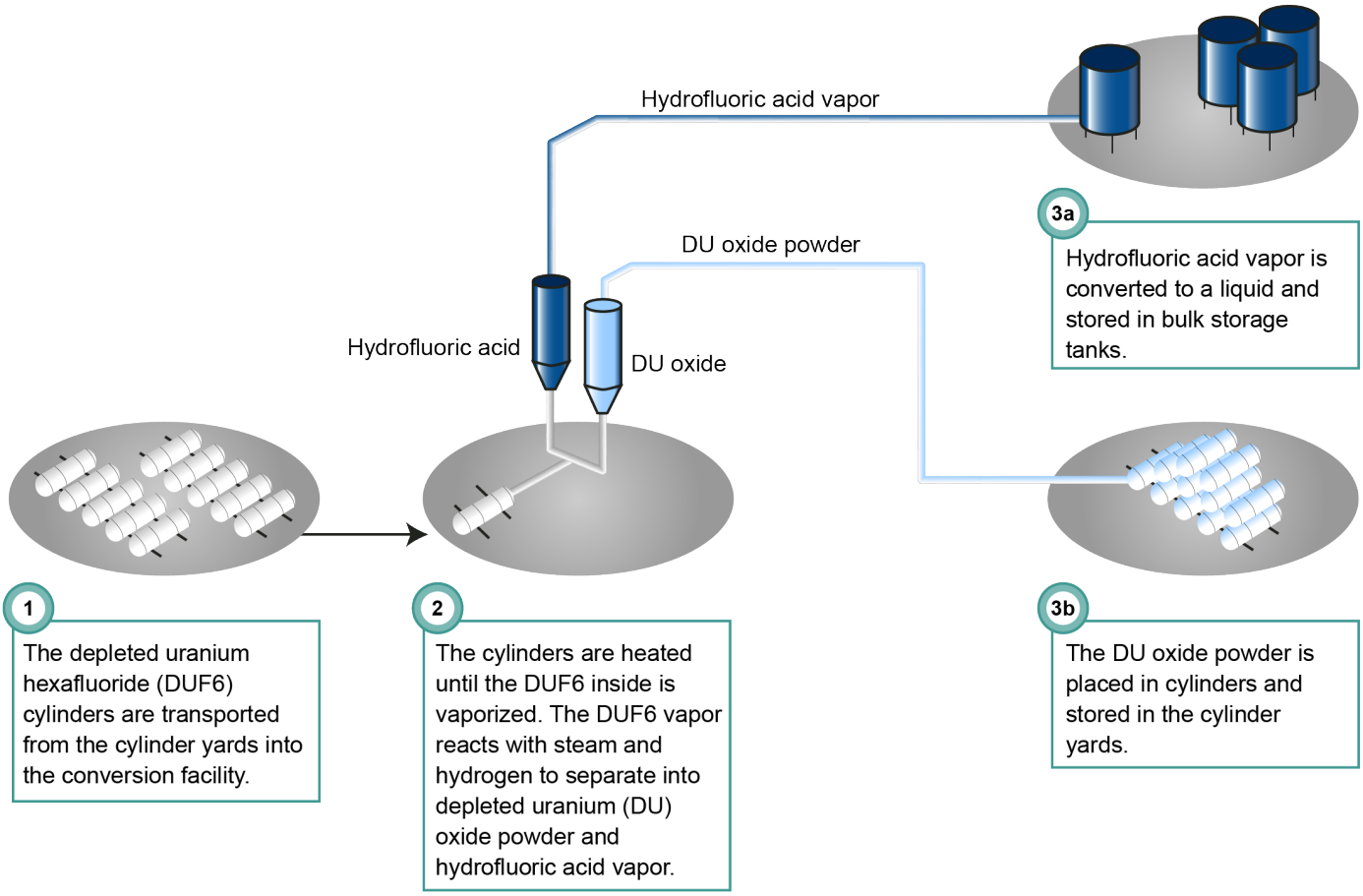
Source: Department of Energy (DOE). | GAO-22-105471

The Portsmouth and Paducah conversion facilities are similar in size and design; however, the Paducah facility has four conversion lines, while Portsmouth has three lines.[14] The conversion process separates DUF6 into DU oxide powder and hydrofluoric acid vapor.[15] The DU oxide is stored in cylinders in the same yards as the DUF6 cylinders—though segregated from the DUF6 cylinders—and the hydrofluoric acid vapor is converted into liquid form and placed in bulk storage tanks until it is sold. See figure 3 below for a representation of the conversion process.

[14]This is in part because Paducah has over twice the amount of DUF6 on-site to convert.

[15]In addition to the primary products of DU oxide and hydrofluoric acid, the conversion process also creates about 26 tons of calcium fluoride per year, which can be sold for commercial reuse or sent to a disposal facility.

**Figure 3: Simplified Representation of the DUF6 Conversion Process**



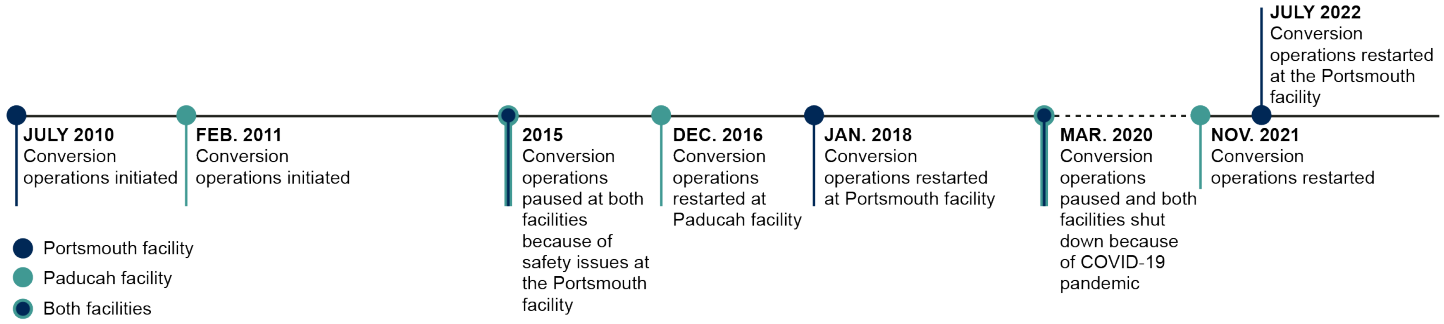

Source: Department of Energy. | GAO-22-105471

EM officials shut down operations at both facilities in March 2020 because of the COVID-19 pandemic. Conversion operations restarted at the Paducah facility in November 2021, and EM officials told us that they restarted conversion operations at the Portsmouth facility in July 2022.

As of January 2022, EM estimated that conversion operations would continue at Portsmouth until 2036 and at Paducah until 2054. These estimates assume that EM will convert the full remaining inventory of over 60,000 DUF6 cylinders and do not take into account the potential transfer of DUF6 to other entities. Once conversion operations are complete, EM officials estimate that it will take 2 years at Portsmouth and 3 years at Paducah to complete decontamination and decommissioning of the

facilities. See figure 4 for the time line of activities at the DUF6 conversion facilities.

**Figure 4: Time Line of Activities at DOE's Depleted Uranium Hexafluoride Conversion Facilities**




Source: GAO analysis of Department of Energy (DOE) documentation. | GAO-22-105471

## Environmental Liability

The federal government is financially liable for cleaning up areas where federal activities have contaminated the environment.[16] Federal accounting standards require agencies responsible for cleaning up contamination to estimate future cleanup and waste disposal costs and to report such costs in their annual financial statements as environmental liabilities. In 2017, we designated the U.S. government's environmental liability as a high-risk area because the liability will likely continue to grow even as billions are spent each year on cleanup efforts.[17]

In fiscal year 2021, the federal government's total environmental liability was $613.3 billion. DOE is responsible for the largest share of the liability ($515.6 billion in fiscal year 2021), which is related primarily to retrieving, treating, and disposing of nuclear and hazardous waste. As of September 30, 2021, EM estimated that the environmental liability associated with DUF6 is $7.2 billion. Of this liability, $4.8 billion is associated with the DUF6 stored at Paducah, and $2.4 billion is associated with the DUF6 at Portsmouth.

[16]Various federal laws, agreements with states, and court decisions require the federal government to clean up environmental hazards at federal sites and facilities, such as nuclear weapons production facilities.

[17]GAO, *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others,* GAO-17-317 (Washington, D.C.: Feb. 15, 2017).

# EM Used COVID-19 Shutdown to Perform Modifications to Conversion Facilities, but the Effect on Cost and Schedule Estimates Is Not Yet Known

## EM Leveraged COVID-19 Shutdown to Perform Modifications to Conversion Facilities

DOE issued a partial stop work order in March 2020, pausing operations at the conversion facilities because of the COVID-19 pandemic. EM officials told us that they leveraged the COVID-19 shutdown of the Paducah and Portsmouth conversion facilities to have the contractor perform maintenance and modifications to the two facilities.

After the onset of the COVID-19 pandemic, MCS followed a phased approach to returning to work during the pandemic in accordance with the overarching guidance from DOE, the Centers for Disease Control, and the Office of Management and Budget:[18]

- **Phase 1.** MCS entered Phase 1 in June 2020, when DOE rescinded the partial stop work order that had shut down the facilities in March. The stop work order had required employees at the conversion facilities to stop any non-mission critical operations and any activities that could not be performed safely in a remote environment. EM officials told us that during Phase 1, some contractor employees continued working at the facilities to maintain regulatory and technical safety requirements. For example, some contractor employees were able to continue working on-site conducting maintenance outside where the cylinders are stored. Other employees that could not safely perform their jobs on-site continued to telework.
- **Phase 2.** In July 2020, MCS entered Phase 2, according to EM officials. During this phase, EM officials directed MCS to resume performing facility modifications that were included in the MCS contract, in order to leverage the time that the facility was shut down during the pandemic. EM officials said that a large portion of the

[18]According to EM officials, DOE moved away from the phased approach in March 2021, when the Secretary of Energy announced a new framework, the Workplace Safety Plan. This framework outlines requirements to protect the health and safety of the DOE workforce, while considering factors such as social distancing and vaccinations.

contractor employees returned to the DUF6 conversion facilities in this phase. EM officials said that they directed employees to start performing modifications that could be done outside to keep employees safe during the pandemic before moving on to performing modifications within the facilities. During this phase, between 30 and 60 employees from each facility continued to telework, out of about 500 employees across both facilities, according to EM officials.

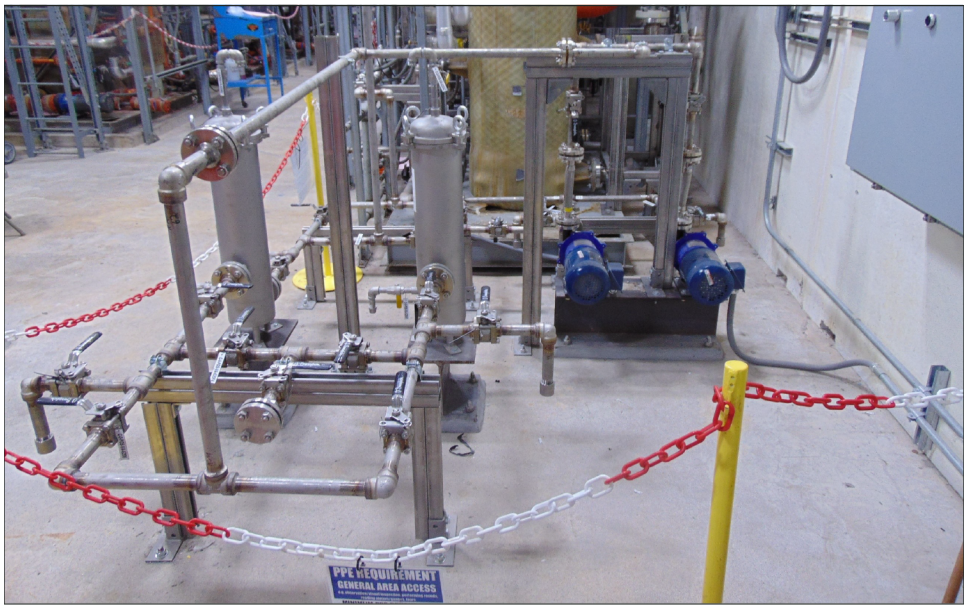
EM officials said that by September 2020, MCS had established full on-site staffing, aside from those employees that could readily telework, and teleworking employees worked on things such as the facilities' environmental compliance. Between September 2020 and November 2021, when conversion operations restarted at the Paducah facility, EM officials said that MCS employees worked to complete modifications and prepare the facilities to restart operations. According to EM officials, beyond November 2021, MCS employees continued preparations to restart the Portsmouth facility. EM officials told us that operations restarted at Portsmouth in July 2022.

According to EM officials, some modifications performed during the shutdown were included in EM's long-term strategic goals and added to authorized work or were already in the contracts for managing the facilities. They told us that, under normal operations, each facility typically fully shuts down annually for maintenance; these planned shutdowns vary in length but, on average, last about 2 months every year. EM officials told us that some of the modifications that EM performed during the COVID-19 shutdown would have required a full-facility shutdown in order to complete them. EM officials said that modifications conducted during the COVID-19 shutdown could decrease the amount of time that the facilities are shut down in the future. Some examples of modifications performed include:

- **Hydrofluoric acid tank upgrade.** EM officials said that they completed additional planned modifications on the hydrofluoric acid storage tanks at both facilities. EM officials said that when the hydrofluoric acid storage tanks were originally installed, they were connected in a way that did not allow for operators to isolate one tank from the group without shutting down the entire facility. MCS employees installed additional valves on the tanks for isolation and venting. According to EM officials, this modification will reduce future interruptions to operations because operators can now isolate a single hydrofluoric acid tank from the group when maintenance is needed.

- **Pipe upgrade.** EM officials told us that when the conversion facilities were originally constructed, the piping used for handling the potassium hydroxide that neutralizes the hydrofluoric acid was made out of PVC pipe; MCS upgraded this to stainless steel pipes in order to prevent future wear on the pipes (see fig. 5).

**Figure 5: Example of Pipe Upgrade at the Paducah DUF6 Conversion Facility**
Pipes carrying potassium hydroxide—used to neutralize hydrofluoric acid during the depleted uranium hexafluoride (DUF6) conversion process—were originally made from PVC. Officials from the Department of Energy's (DOE) Office of Environmental Management (EM) replaced the PVC pipes with stainless steel.




Source: Department of Energy. | GAO-22-105471

From April 2020 through November 2021, EM spent about $163 million on plant modifications and general maintenance, pandemic-related costs,

and various operations costs.[19] According to EM officials, this is similar to expenditures under normal operations.[20]

According to MCS data, EM spent this $163 million on three main categories of work:[21]

- **Facility maintenance and modifications.** EM spent roughly $47.4 million on maintenance, utilities, and plant modifications from April 2020 to November 2021. These costs were split between the two sites: $22.9 million at Paducah and $24.4 million at Portsmouth. These costs covered activities such as system maintenance, site utilities, and specific modifications performed.
- **Pandemic-related costs.** EM incurred about $54.4 million in costs for pandemic-related items such as personal protective equipment, paid leave for vaccines and quarantine, and paid leave for employees who could not safely perform on-site work.
- **Various operation costs.** EM spent about $61.3 million from April 2020 to November 2021 on other various operation costs. These costs cover items such as waste management, emergency preparedness, information technology, and subcontractors for various projects.

## EM Is Assessing Various Effects on Cost and Schedule Estimates While Restarting Conversion Operations

EM officials are considering several factors, including the effect of the COVID-19 shutdown, as they update the DUF6 facilities' cost and schedule estimates. EM officials restarted conversion operations at

[19]While the COVID-19 shutdown began in March 2020, we are not including March cost data because during that month normal operating costs were aggregated with COVID-19-related costs. For reporting purposes, we will only use data that clearly reflect the COVID-19 shutdown period.

[20]EM spent on average $94 million a year to operate the conversion facilities during normal operating status in the 2 years leading up to the COVID-19 pandemic, from March 2018 through March 2020. EM officials in the Portsmouth/Paducah Project Office provided us with monthly cost data collected by the facilities' contractor MCS for each month of the 2 years prior to the COVID-19 shutdown in 2020, organized by category of costs.

[21]EM officials in the Portsmouth/Paducah Project Office provided us with monthly cost data collected by the facilities' contractor MCS for each month of the shutdown and organized by category of costs.

Paducah in November 2021, and EM officials told us they restarted operations at the Portsmouth facility in July 2022.

## Cost and Schedule Estimates

EM officials told us that they are developing new cost and schedule estimates for the life cycle of the conversion facilities to assess the effect of the prolonged shutdown on its conversion mission timeline and budget. EM officials in PPPO said that they are developing new estimates based on a new EM program management protocol focused on using actual costs and historical values for production rather than predicting future values.[22] EM officials noted that they will revisit the estimates annually and hope to see the benefits of the plant modifications when they adjust the estimate next year.

EM officials said that they are currently reassessing the schedule for the conversion facilities and will consider several factors, including the impact of the shutdown. EM officials told us that they could update the schedule estimate by including various considerations, such as:

- **Calculating the shutdown period the same way they did after a previous shutdown.** EM officials told us that, following the 3-year shutdown from 2015 to 2018, they added 3 years to the schedule estimate. If EM officials were to calculate schedule changes similarly, it could add roughly 19 to 27 months to the schedule estimates, equal to the amount of time each facility was shut down because of COVID-19 and facility modifications. Prior to the COVID-19 shutdown, EM estimated that Portsmouth would continue conversion operations until 2036 and Paducah until 2054. If the updated schedule were calculated according to precedent, Portsmouth would be scheduled to operate until about 2038 and Paducah until about 2057.
- **Experiencing maintenance issues from extended time without operation.** EM officials said that they had experienced a few technical issues when restarting operations after the COVID-19 shutdown that may add to cost and schedule. For example, they said that there was an issue with a component in the Paducah conversion facility that

[22]DOE's new program management protocol requires that EM program plans be driven by consistent prioritization principles, be informed by validated life-cycle cost and schedule estimates and risk assessments, incorporate GAO best practices for program and project management, and be updated to reflect analyses of strategic alternatives. Department of Energy, *Issuance of the Environmental Management Program Management Protocol* (Washington, D.C.: Nov. 6, 2020).

required replacement, which had not posed an issue prior to the shutdown. As a result, EM officials told us that they have only been operating a portion of the conversion lines since the Paducah restart.

- **Performing modifications to enhance facility functionality.** EM officials told us that they may shorten or avoid future additional shutdowns because of the modifications performed during the COVID-19 shutdown. For example, EM officials told us in March 2022 that the modification to the backup bulk hydrogen system had recently prevented a potential 3-to-5 week shutdown.
- **Transferring DUF6 to other entities:** DOE has three agreements to transfer nearly 30,000 DUF6 cylinders to other entities, as discussed below. In these cases, EM would not have to convert the DUF6 to DU oxide. EM officials told us that, using 2019 conversion rates, the two facilities can convert approximately 1,000 cylinders in total, annually.[23] The officials added that they are using this rate to model the various DUF6 transfer scenarios that could affect their updated cost and schedule estimates. Assuming that the facilities will continue to convert cylinders at this rate, if these three agreements to transfer DUF6 come to fruition, EM could collectively reduce its conversion schedule by roughly 30 years.

As of July 2022, officials in PPPO told us that they were finalizing the new cost and schedule estimates and planning to send the estimates to EM headquarters for approval by the end of 2022. Until EM completes its cost and schedule estimates, the effect of the COVID-19 shutdown on EM's conversion mission will be unknown.

## Paducah Operations

EM officials restarted conversion operations at Paducah in November 2021.[24] MCS had reestablished full on-site staffing, excluding employees who could telework, in September 2020; however, EM officials had to

[23]We found that this rate is consistent with historical rates since the conversion facilities began operating. Over the 6 full years that the facilities had operated through March 2020 (not including the roughly 3 years both facilities were shut down because of safety issues), the facilities converted, on average, 1,100 cylinders per year.

[24]EM officials said that they attribute the shutdown of both facilities from March 2020 through November 2021—when operations restarted at Paducah—to the COVID-19 pandemic. The continued shutdown of the Portsmouth facility from November 2021 until July 2022—when operations restarted at Portsmouth—is attributed to maintenance and plant modifications.

complete certain activities before restarting conversion operations, including:

- **Finishing modifications.** EM officials told us that certain modifications they had started required a full-facility shutdown to be performed. They said that employees needed to finish the modifications before operations could resume.
- **Performing dry-runs.** Leading up to restarting conversion operations, MCS employees performed dry-runs of the conversion processes to assess and address any issues that they may encounter when restarting operations after an extended shutdown.
- **Completing the readiness assessment.** DOE officials completed a readiness assessment to verify that personnel and equipment were in place and functional and had achieved an adequate state of readiness to restart DUF6 operations. In its readiness assessment, DOE identified two findings regarding proper documentation of certain processes, which needed to be addressed prior to restarting conversion operations.

Because COVID-19 physical distancing requirements limited the number of people in the control room, and to ensure sufficient operations oversight, EM officials said that they initially restarted operations on one conversion line.[25] EM officials told us that they allowed the restarted line to run for about a week before adding an additional line, one at a time. As of March 2022, EM officials said that conversion operations were running similar to prepandemic production and that three of four conversion lines were operating. According to EM officials, they had to shut down the Paducah facility again in June 2022 to address technical issues. EM officials told us that they expect to resume operations in August 2022.

## Portsmouth Operations

EM officials told us that they restarted operations at Portsmouth in July 2022. EM officials also told us that they performed additional modifications at the Portsmouth facility, which delayed its restart. For example, EM officials said that they upgraded the existing integrated control system because the original system was no longer supported by the vendor. According to EM officials, this system has two primary functions. The first function allows remote operation of the pumps and

[25]In each facility, the equipment used to convert the DUF6 is arranged in parallel lines. The Paducah facility has four lines, and the Portsmouth facility has three.

plant functions, while the second function allows operators to close valves in case of a safety emergency.

## EM Has Agreements to Provide Some DUF6 to Other Entities, but Authority for One Agreement Is Doubtful

EM has two agreements to provide DUF6 to NNSA and a third agreement to sell DUF6 to a private company, which would reduce the inventory of DUF6 that EM would have to convert. EM has begun activities to transfer DUF6 to one of the NNSA programs, but the timing of when EM might transfer ownership of DUF6 to the second NNSA program is uncertain. EM has not yet sold DUF6 to the private company but, under current law, DOE's authority to do so in the future is doubtful.

### EM Has Two Agreements to Provide DUF6 to NNSA, but the Plans and Timing for One Agreement Are Uncertain

EM has agreements to provide DUF6 to two NNSA programs: (1) the Tritium and Domestic Uranium Enrichment Program and (2) the Depleted Uranium (DU) Modernization Program. Transferring ownership of the agreed-upon amounts of DUF6 to NNSA for these two programs would decrease the amount of DUF6 that EM would need to convert by about 5,500 cylinders. EM officials estimate that this could save EM about 5.5 years of conversion operations.[26]

#### NNSA's Tritium and Domestic Uranium Enrichment Program

In February 2020, EM signed an agreement to reserve and transfer ownership of a portion of the DUF6 inventory located at the Portsmouth site to NNSA's Tritium and Domestic Uranium Enrichment Program. In the agreement, EM identified approximately 4,200 cylinders that meet the

[26]EM officials estimate that the two facilities convert a total of about 1,000 cylinders per year. This estimate is based on the amount of DUF6 converted in fiscal year 2019.

needs of the program.[27] NNSA plans to use this DUF6 to support future national security uranium enrichment activities.[28]

EM has started activities to provide the agreed-upon inventory to the Tritium and Domestic Uranium Enrichment Program. In January 2022, EM officials told us that EM had moved 100 cylinders into a facility at Portsmouth, where the DUF6 is being prepared for transport to an NNSA site. In order to transport the DUF6 to NNSA, the DUF6 has to be transferred from thin-wall cylinders to thick-wall cylinders.[29] According to NNSA officials, as of May 2022, 59 of the 100 cylinders had been transferred to thick-wall cylinders and sampled. NNSA officials said that they had reviewed the samples to ensure that the DUF6 meets program needs, but they had not yet sent the final documentation to EM.

While EM is responsible for transferring DUF6 into the thick-wall cylinders, NNSA is funding all work associated with the transfers. This includes the costs of cylinder procurement and transfer operations, such as maintenance of the facility used to transfer the DUF6 from thin-wall cylinders to thick-wall cylinders and any necessary upgrades.[30]

EM will transfer ownership of DUF6 to the Tritium and Domestic Uranium Enrichment Program incrementally. According to the agreement, only about 1,200 cylinders will initially be provided to NNSA. The remaining 3,000 cylinders will be reserved until 2035 or until EM completes the conversion of the DUF6 inventory not currently reserved for other entities, whichever comes first. As of May 2022, EM and NNSA officials said that, aside from the 59 cylinders already sampled, they had no additional plans to transfer DUF6 to NNSA's Tritium and Domestic Uranium Enrichment Program.

[27]Needs of the program include DUF6 with an assay range of 0.351 percent to 0.706 percent uranium-235.

[28]Long-standing policy requires that defense missions—such as tritium production—require the use of "unobligated" uranium—that is, material without peaceful use restrictions. Because EM has been working to disposition DUF6 inventories, NNSA pursued this agreement to secure inventories that may be needed to support future national security enrichment activities.

[29]The DUF6 must be transported in thick-wall cylinders per Department of Transportation and International Atomic Energy Agency requirements.

[30]EM would still be responsible for disposition of the thin-wall cylinders.

Prior to completion of its conversion operations at Portsmouth—currently planned to be in 2036—EM will provide NNSA with a 2-year advance notification. Once EM has completed its conversion mission at Portsmouth, NNSA would assume responsibility for on-site storage, maintenance, inspection, relocation, and management of any remaining DUF6 reserved for the Tritium and Domestic Uranium Enrichment Program. In turn, NNSA would provide EM with a 2-year advance notification, should NNSA determine that it no longer requires DUF6.

## NNSA's Depleted Uranium Modernization Program

In June 2015, EM signed a memorandum of agreement with NNSA's Office of Defense Programs to reserve portions of the DUF6 inventory at both the Portsmouth and Paducah sites for the production of DUF4. This agreement is effective until at least fiscal year 2030, at which time NNSA and EM would evaluate future needs. NNSA officials told us that they are considering extending the agreement beyond the current fiscal year 2030 reservation date.

NNSA plans to use this DUF6 to support the agency's continuing need for high-purity depleted uranium metal (DU metal) for the nuclear weapons

**NNSA Mitigation Tactics for Obtaining DU Metal**

According to NNSA officials, they are looking at ways to mitigate the effect of delaying the construction of the depleted uranium tetrafluoride (DUF4) line in the Portsmouth depleted uranium hexafluoride (DUF6) conversion facility. For example, NNSA officials said that they are researching technologies such as cold hearth melting, a process that uses a heat source for alloying metal, or recycling scrap to create high-purity depleted uranium (DU) metal. NNSA officials said that they are also looking at a technology that would use scrubbers to remove impurities from recycled Department of Defense munitions, which would then be converted to high-purity depleted uranium. NNSA officials told us that these technologies would not be alternatives to constructing a DUF6-to-DUF4 conversion capability because they would not produce enough high-purity depleted uranium to meet NNSA's needs. Rather, they would help buffer the tight schedule for obtaining DUF4 by 2026 in order to create the needed DU metal.

Source: National Nuclear Security Administration (NNSA). | GAO-22-105471

stockpile.[31] To produce the DU metal, DUF6 must first be converted into DUF4. In September 2018, EM and NNSA reached an agreement to proceed with the design and construction of a DUF6-to-DUF4 conversion line, which would be added to the Portsmouth DUF6 conversion facility.[32] The DUF4 will then be converted to DU metal and sent to NNSA's Y-12 National Security Complex (Y-12) in Oak Ridge, Tennessee.[33] EM is currently reserving 1,269 DUF6 cylinders for the DU Modernization Program, the majority of which are located at Paducah. In its agreement with NNSA, EM initially identified approximately 1,155 cylinders that would meet NNSA's requirements; however, in April 2020, EM identified an additional 114 cylinders to reserve for the DU program.[34]

The timing for when EM may begin transferring ownership of DUF6 to NNSA for the DUF4 program is uncertain because NNSA's plans for converting DUF6 to DUF4 are currently in flux. According to NNSA officials, the DUF6-to-DUF4 conversion line project was paused in March 2021 because of an increase in the project cost estimate from $38 million to $58 million. For projects costing over $50 million, DOE project management processes require that NNSA conduct an analysis of

[31]We previously reported on NNSA's need for DUF4 and potential plans to build an NNSA line at the Portsmouth conversion facility. See GAO, *Nuclear Weapons: NNSA Plans to Modernize Critical Depleted Uranium Capabilities and Improve Program Management,* GAO-21-16 (Washington, D.C.: Oct. 15, 2020).

[32]The Portsmouth DUF6 conversion facility only has three conversion lines, leaving room for NNSA to install a conversion line to convert DUF6 to DUF4. NNSA announced its intention to build this fourth conversion line in January 2020. Amended Record of Decision for the Installation and Operation of a Depleted Uranium Hexafluoride Conversion Facility at the Portsmouth, Ohio Site, 85 Fed. Reg. 3,903 (Jan. 23, 2020).

[33]The Y-12 National Security Complex is one of NNSA's nuclear weapons production plants. Located in Oak Ridge, Tennessee, Y-12's primary role in supporting the modernization of the nuclear weapons stockpile is the refurbishment and manufacture of secondary stages of nuclear weapons and related components. These components may include enriched uranium and depleted uranium.

[34]According to EM officials, requirements include that the DUF6 has an assay level of 0.200 +/- 0.007 percent uranium-235; that the cylinder containing the DUF6 has only been filled and sealed once; and that the cylinder has been stored on concrete pads.

alternatives. NNSA officials say that they plan to start the analysis of alternatives for converting DUF6 to DUF4 by the end of fiscal year 2022.[35]

NNSA officials told us that they would need to acquire DUF6 from EM regardless of the alternative they choose in order to meet the need to have high-purity DU metal by fiscal year 2030.[36] According to NNSA officials, they would need to produce DUF4 by January 2026 to meet the 2030 date for DU metal. The latest schedule estimate for the DUF4 conversion line has design finished by April 2024 and operations beginning in the first half of fiscal year 2026.[37] However, NNSA officials told us that it would be difficult for the new DUF6-to-DUF4 conversion line at Portsmouth to be operating by the beginning of fiscal year 2026 because of the time required to implement DOE's program management processes.

## EM Has an Agreement to Sell DUF6 to a Private Company, but Authority to Do So Is Doubtful

EM has an agreement to sell DUF6 to a private company, Global Laser Enrichment.[38] The agreement reserves about 24,300 cylinders of DUF6

[35]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B, Chg 6 (Washington, D.C.: Jan. 12, 2021). According to NNSA officials, the additional processes required by DOE for projects estimated to cost over $50 million added additional costs and pushed the DUF4 conversion line cost estimate to about $100 million.

[36]One of the alternatives that NNSA will look at is the use of private companies to convert DUF6 to DUF4 at other facilities. According to NNSA officials, two private companies have expressed interest in developing capabilities to convert DUF6 to DUF4, including one company that previously produced DUF4 for NNSA over a decade ago. If one of these alternatives were selected, it would take the place of the proposed DUF4 line in the Portsmouth facility.

[37]After converting the DUF6 to DUF4 at the Portsmouth facility, NNSA would transport the DUF4 to a commercial vendor for conversion to DU metal.

[38]EM officials told us that, in addition to the three agreements to reserve and transfer DUF6 to NNSA and GLE, the office in charge of the DUF6 facilities receives routine interest in small quantities of DUF6. For example, EM officials said that they have had preliminary discussions with Oak Ridge National Laboratory (ORNL) to provide the laboratory with one or two cylinders of DUF6. If ORNL continues to pursue this, EM officials said that they would ensure that the cylinders transferred to ORNL were consistent with the existing agreements and that cylinders already reserved for other entities would not be transferred to ORNL.

located at the Paducah site for future sale.[39] EM would sell DUF6 to GLE in exchange for natural uranium hexafluoride.[40] According to EM officials, selling the agreed-upon amount of DUF6 to GLE could save EM an estimated 24 years of conversion operations and potentially over $2 billion in operating costs.[41] This agreement is contingent on GLE constructing and beginning operations of a laser enrichment facility at the Paducah site by the end of 2030.[42]

EM has not yet begun sales of DUF6 to GLE, as GLE has not yet constructed the Paducah Laser Enrichment Facility. As of May 2022, GLE representatives told us that they were taking steps toward licensing and construction of the Paducah Laser Enrichment Facility, though they were unable to share the timelines for the completion of these activities because of commercial sensitivities. However, GLE representatives told us that they believe they are on schedule to meet their obligations as described in the agreement with EM. For example, GLE representatives told us that they have spent time in Kentucky identifying where to build the facility and that they have been meeting with both DOE officials and Nuclear Regulatory Commission officials.[43] According to GLE representatives, as of May 2022, GLE is also evaluating how it could help fill U.S. nuclear energy industry needs for low-enriched uranium and conversion because of concerns about U.S. reliance on nuclear fuel supply from Russia. GLE representatives said that acquiring DUF6 from EM would be essential for GLE to carry out these plans.

In addition to the approximately 24,300 cylinders already reserved under the current agreement, GLE has also expressed interest in acquiring additional DUF6 cylinders at the Portsmouth site that are currently

[39]EM first signed an agreement with GLE in 2016. The agreement was last updated in May 2020.

[40]According to EM officials, the DOE office that would use the natural uranium hexafluoride and the reasons for the use would depend on national priorities at the time.

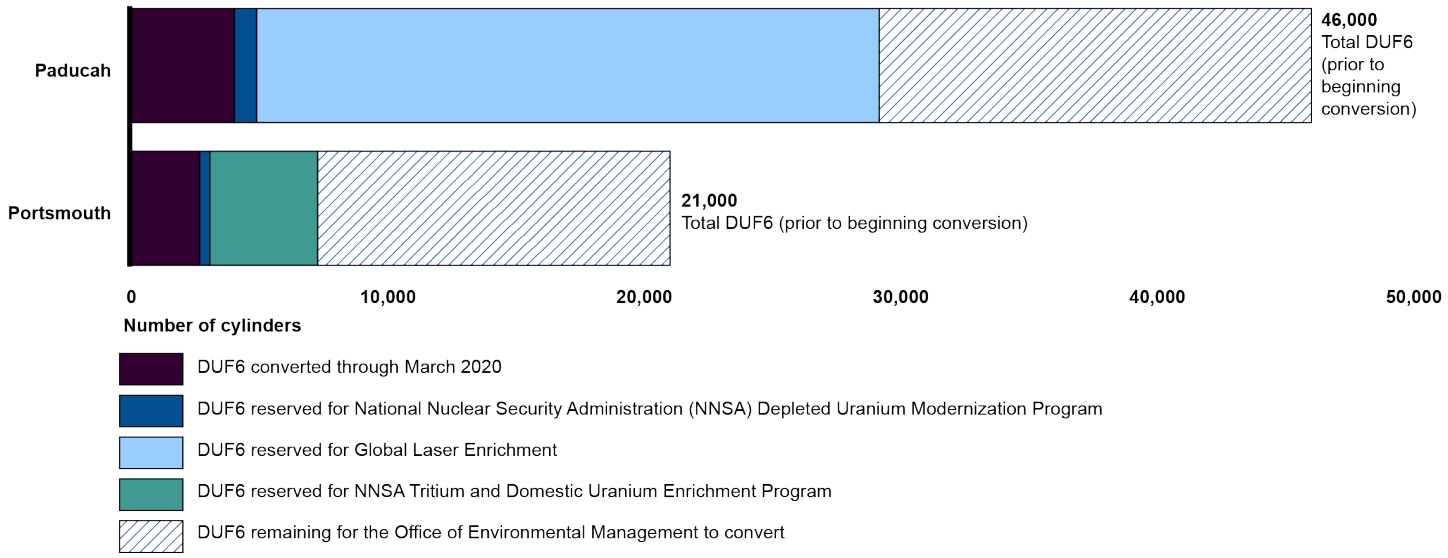
[41]This amount assumes that EM's operating costs are about $94 million per year. EM spent, on average, $94 million a year to operate the conversion facilities under normal operating status in the 2 years leading up to the COVID-19 pandemic.

[42]GLE plans to use the Paducah Laser Enrichment Facility to reenrich DUF6 into natural uranium for sale into the global market. Natural uranium has an assay level of 0.7 percent uranium-235 and may be used for fuel in certain foreign nuclear reactor designs.

[43]The Nuclear Regulatory Commission licenses and regulates civilian use of radioactive materials.

reserved for NNSA.[44] According to GLE representatives, they are interested in all DUF6 with an assay level at or above 0.25 percent uranium-235. However, they also said that they would be open to evaluating DUF6 of other assay levels for use. See figure 6 below for a breakdown of the full DUF6 inventory.

**Figure 6: Breakdown of DOE's Depleted Uranium Hexafluoride (DUF6) Inventory**




Source: GAO analysis of Department of Energy (DOE) documentation. | GAO-22-105471

[44]According to the agreement between EM and GLE, GLE would have rights to any DUF6 at Portsmouth that NNSA does not require by the end of 2035.

**Accessible Data Table for Figure 6**

| | # of cylinders @ the Paducah site | # of cylinders @ the Portsmouth site |
|---|---|---|
| **Total DUF6 (prior to beginning conversion)** | 46,000 | 21,000 |
| **DUF6 converted through March 2020** | 4,006 | 2,663 |
| **DUF6 reserved for National Nuclear Security Administration (NNSA) Depleted Uranium Modernization Program** | 873 | 396 |
| **DUF6 reserved for Global Laser Enrichment** | 0 | 4,198 |
| **DUF6 reserved for NNSA Tritium and Domestic Uranium Enrichment Program** | 24,275 | 0 |
| **DUF6 remaining for the Office of Environmental Management to convert** | 16846 | 13743 |

EM officials believe that they have the authority to sell DUF6 to GLE. According to EM officials, the Department of Energy Organization Act and the Atomic Energy Act of 1954, as amended, authorize EM to enter into agreements and to sell, transfer, exchange, store, and accept special nuclear, source, and by-product material.[45]

However, as we stated in 2008, we believe that DOE's legal authority to sell its depleted uranium inventory is doubtful.[46] We reported that 1996 legislation governing DOE's disposition of its uranium dictates that DOE

[45]Department of Energy Organization Act, Pub. L. No. 95-91, 91 Stat. 565 (1977) (codified as amended at 42 U.S.C. §§ 7101-7352); Atomic Energy Act of 1954, ch. 1073, 68 Stat. 921 (codified as amended at 42 U.S.C. §§ 2011-2297g-4).

[46]GAO, *Nuclear Material: DOE Has Several Potential Options for Dealing with Depleted Uranium Tails, Each of Which Could Benefit the Government*, GAO-08-606R (Washington, D.C.: Mar. 31, 2008). In this report, we recommended that Congress consider clarifying DOE's statutory authority to manage depleted uranium, including explicit direction about whether and how DOE may sell or transfer the tails in their depleted form. As of June 2022, Congress has not passed legislation clarifying DOE's authority to sell or transfer depleted uranium.

may not sell "any" uranium except as consistent with its provisions.[47] While the legislation then specifies the conditions for DOE's sale or transfer of a number of certain types of uranium—including ensuring that certain transactions do not have an adverse material impact on the domestic uranium industry—it does not specify conditions for the sale or transfer of depleted uranium, including DUF6. Therefore, DOE likely lacks such authority.

Clarifying DOE's legal authority to sell DUF6 may help DOE avoid litigation that could interrupt DOE's efforts to sell DUF6. If there were litigation, it could affect the amount of time it takes EM to complete its mission to convert or transfer ownership of DUF6. Taking such action and specifying the conditions for sales of DUF6, such as requiring that DOE conduct a market impact study, could also help ensure that sales of DUF6, like the sale of other types of uranium in the government's inventory, do not adversely affect the uranium industry. Further, providing DOE with clear authority to transfer depleted uranium would better position EM to reduce its conversion operations timeline. This would save long-term costs and reduce the environmental liabilities associated with managing DUF6 and operating the conversion facilities. In addition, clarifying this authority could help assure a future supply of low-enriched uranium for the nuclear energy industry in the United States, lowering industry dependence on foreign low-enriched uranium supply.

## EM Has Identified Options for Managing Conversion Products, but Some Plans Are Not Finalized

EM has identified options for disposing of DU oxide—one of two primary products of the DUF6 conversion process—but EM has not yet begun the disposal process. EM officials told us that this is in part because they have been waiting for funding for disposal operations. In addition, EM has worked with NNSA to identify some options for reusing DU oxide. EM also has a process to manage hydrofluoric acid, the other primary conversion

[47]The Atomic Energy Act of 1954, as amended, gives DOE general authority under certain conditions to sell, lease, distribute, or otherwise make available source material, including uranium. Congress, however, limited this authority in 1996 when it passed the USEC Privatization Act. This act prohibits the Secretary of Energy from transferring or selling any uranium except as consistent with the act's specific terms and conditions. USEC Privatization Act, Pub. L. No. 104-134, § 3112, 110 Stat. 1321, 1321-344, 42 U.S.C. § 2297h-10.

product. Since 2006, EM has authorized its contractor to sell the hydrofluoric acid to a private company and apply the proceeds of those sales to offset contract costs.

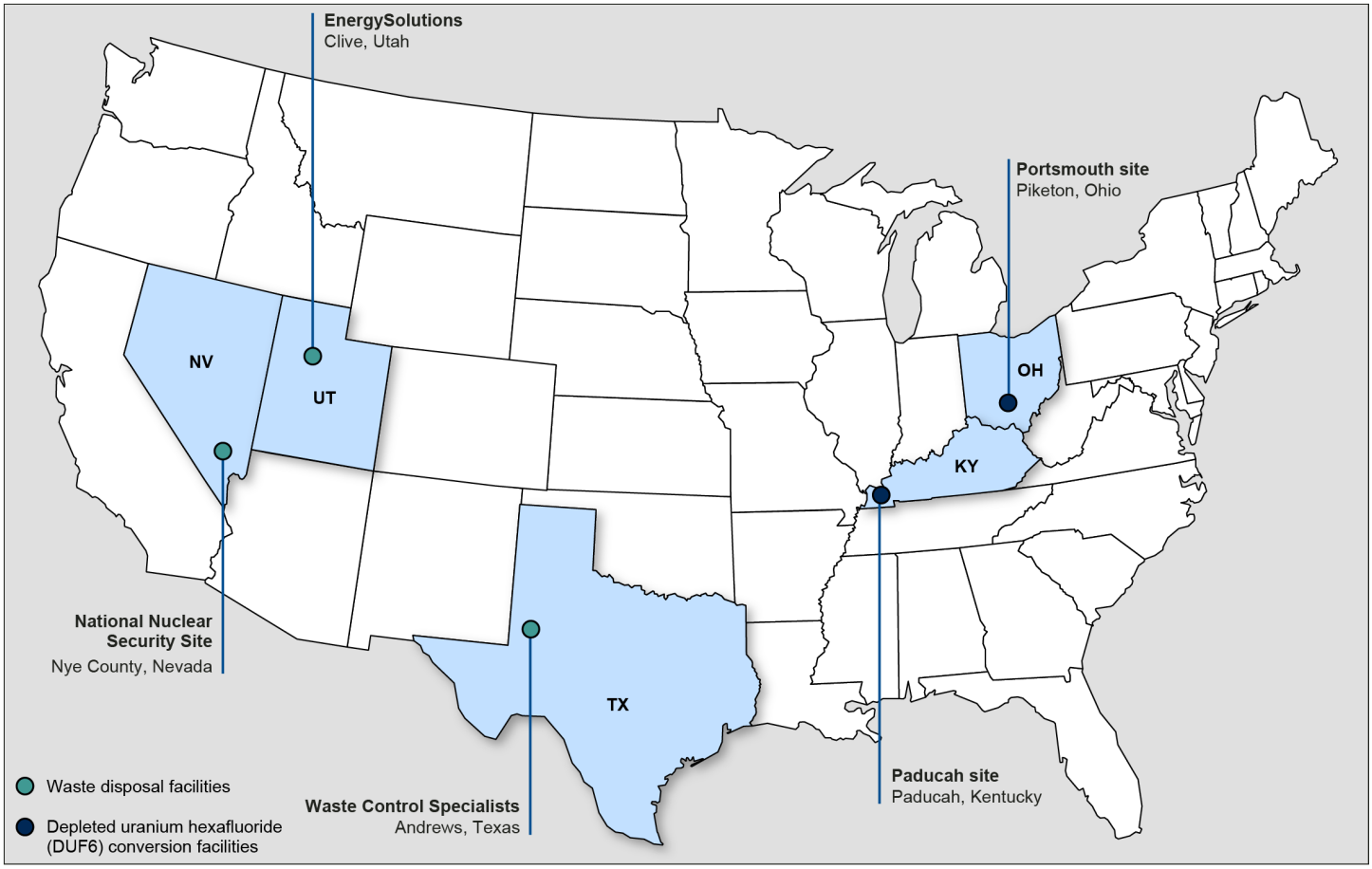
## EM Has Identified Disposal Options for DU Oxide and Other Conversion Products but Has Not Begun Disposing of DU Oxide

EM has identified three waste disposal sites for the disposition of DU oxide (see fig. 7). In April 2020, EM issued its final supplemental environmental impact statement for disposition of DU oxide.[48] In this document, EM identified the agency's preference to dispose of DU oxide waste at one or more of three disposal facilities: (1) EnergySolutions, a commercial low-level radioactive waste disposal facility near Clive, Utah; (2) Waste Control Specialists (WCS), a commercial low-level radioactive waste disposal facility near Andrews, Texas; and (3) the Nevada National Security Site (NNSS), a federal facility located in Nye County, Nevada.[49]

[48]Department of Energy Office of Environmental Management, *Final Supplemental Environmental Impact Statement for Disposition of Depleted Uranium Oxide Conversion Product.*

[49]EM will dispose of some or all of the DU oxide inventory as waste, if EM cannot find a beneficial way to reuse the product.

**Figure 7: Map of Potential Disposal Facilities for Depleted Uranium Oxide**




Sources: Department of Energy and Map Resources (map). | GAO-22-105471

All three of these facilities are permitted to accept low-level radioactive waste, such as DU oxide. However, according to disposal facility representatives, two of these facilities need special permitting to accept the large quantity of DU oxide waste that EM expects to produce, assuming that EM converts the full inventory of DUF6. By the end of DUF6 conversion operations, EM expects to produce up to 69,000 cylinders of DU oxide for disposal, if the entire DUF6 inventory is converted. About 46,000 of those cylinders would be located at Paducah and about 23,000 cylinders at Portsmouth. EM estimates that it will take about 15 years from Portsmouth and 32 years from Paducah to ship the full inventory of DU oxide to a waste disposal site.

According to the information presented in EM's environmental impact statement, some factors that could affect where EM is able to send the DU oxide include if the facility has a permit to accept the waste, if the facility will have the capacity to accept the waste, and if the facility will be open long enough to accept the waste. For example:

- **WCS.** According to WCS representatives, they are fully licensed by the State of Texas—under authority from the Nuclear Regulatory Commission as an agreement state—to accept the DU oxide waste under Nuclear Regulatory Commission disposal requirements, and the Texas regulator has fully vetted and agreed to WCS receiving DU oxide.[50] Representatives from WCS noted that its license will be up for renewal in 2024, and they expect full renewal of the license. WCS has disposed of a pilot shipment of six cylinders of DU oxide from the Paducah facility. Specifically, in September 2020, the contractor that operates the DUF6 conversion facilities shipped six cylinders of DU oxide waste to WCS as part of a pilot shipment to compare two rail transportation methods. According to WCS representatives, this pilot shipment also demonstrated WCS's capability to receive and bury DU oxide waste.

  According to WCS representatives, there is no limitation on the amount of DU oxide that WCS can receive under its license, meaning WCS could accept as much waste as EM wanted to send to the site. However, representatives also noted that WCS is currently working with a tentative closing date of 2044, though WCS officials intend to request renewals to stay open beyond that date.

- **EnergySolutions.** According to EnergySolutions representatives, they are still in the process of obtaining the necessary license to dispose of DU oxide and believe that they will have the license by the end of 2022. However, Utah regulatory officials indicated to us that it may take longer than that because of both the application review time and anticipated public interest in the disposal of DU oxide in Utah. For example, state regulatory officials told us that it is likely the public will raise concerns about issues including transportation and effects on groundwater. In addition, state regulatory officials explained that once their division deems EnergySolutions' application for the DU oxide disposal license to be complete, it will need to go through the public

[50]An agreement state is a state that has an agreement with the Nuclear Regulatory Commission under which the state assumes, and the Nuclear Regulatory Commission discontinues, regulatory authority over specified radioactive materials in accordance with the Atomic Energy Act of 1954, as amended.

comment process. After the division addresses comments, they then issue a decisional document, at which point the public has the option to file a legal appeal. Regulatory officials told us that there is at least one public interest group that may file an appeal in this instance.

EnergySolutions representatives told us that the facility would be able to accept the waste over the planned 32-year shipping time frame. However, according to EnergySolutions representatives, the size of the proposed disposal cell will only be able to take up to 70 percent of EM's DU oxide waste. The state would require an amendment to EnergySolutions' license to accept additional waste because it would need to increase the size of the disposal cell.

- **NNSS.** An NNSS official told us that NNSS must follow a regulatory process that typically lasts a couple months before the facility can accept a particular waste, and that process has not been completed for DU oxide. However, this NNSS official told us that obtaining permission from the state of Nevada to accept the waste would likely be time consuming. For example, the official said that the state of Nevada may be concerned about accepting such a large amount of waste at NNSS for disposal when there are commercial facilities that could take the waste instead.

  The NNSS official believes that NNSS has the space to accept the full inventory of DU oxide. However, NNSS is currently planning to close in 2030. The NNSS official said that they are working with DOE to determine what will happen after 2030—including the possibility that the facility will stay open past that date—but no decisions have been made.

EM issued a record of decision to dispose of DU oxide at one or more of the three disposal facilities, but EM has not yet made a final decision about which facilities it will use.[51] EM officials told us that they do not have an immediate need to dispose of the DU oxide waste, and officials noted that they may not make a decision on where to send the waste until after 2022. EM officials also told us that they have been waiting for funding for disposal operations, which the officials said the agency received for the first time in the fiscal year 2022 budget. According to EM officials, they will base their final decision on where to send the waste on the capabilities of the facility as well as the best price they receive in bids

[51]85 Fed. Reg. 34,610 (June 5, 2020).

from the disposal facilities. Officials noted that they will also take into account transportation costs.

Transportation costs will depend in part on the manner of transportation that EM can use to ship the DU oxide to a disposal facility. Both WCS and EnergySolutions have rail access, so EM could ship DU oxide directly from Paducah and Portsmouth to either facility. However, NNSS does not have a direct rail line connection, so EM would have to transfer the DU oxide from the rail cars to trucks at a transfer facility.[52] According to EM officials, every rail car in a train shipment would require six trucks to transport the cylinders from a transfer facility to NNSS, as a truck can only carry one cylinder.

EM officials identified cost and schedule benefits to having all three facilities as options for DU oxide waste disposal. Using three facilities would provide EM with greater flexibility. For example, if one or more facility halted shipments for any reason, having more than one facility as an option would allow EM to continue disposal and stay on schedule. EM officials also noted that having two commercial facility options increases competition and allows the government to receive the best disposal rate.

Until EM transports DU oxide waste to one or more of the waste disposal facilities, EM will store the DU oxide at the Paducah and Portsmouth conversion facility sites. According to the supplemental environmental impact statement, this would not be a final disposition and would only defer the disposition decision to a later date. Regulators from the state of Ohio also told us that their state would likely significantly object to storing the waste at the Portsmouth site for a significant period because it would impact the state's ability to reuse the surrounding land for other purposes.

EM is also working with NNSA to determine if there is a beneficial way to reuse some DU oxide instead of disposing of it. In February 2022, EM transferred two drums of DU oxide from the Portsmouth site to Y-12 in

[52]The supplemental environmental impact statement assumes that this transfer would happen in Barstow, California, and the trucks would travel approximately 200 miles from Barstow to NNSS. However, EM officials noted that they would also evaluate alternate transfer facilities closer to NNSS, as closer facilities would lower the overall transportation costs.

Oak Ridge, Tennessee.[53] NNSA needs DU oxide in order to test and evaluate equipment for the Uranium Processing Facility at Y-12, which is intended to provide a facility for enriched uranium processing capabilities.[54] According to EM officials, they are not currently planning to send more DU oxide to Y-12, as the amount sent met project needs. However, they have also discussed sending 50 to 60 drums of DU oxide to DOE's Savannah River Site for additional research in the future.

EM has identified options for managing or disposing of other products of the DUF6 conversion process. Hydrofluoric acid can be sold (as discussed below). Other products—calcium fluoride, empty cylinders, and heel cylinders—are considered low-level radioactive waste and can be sent to an off-site disposal facility, according to the supplemental environmental impact statement.[55] Calcium fluoride that meets certain requirements can also be disposed of at local landfills. According to EM officials, they have already begun disposal of calcium fluoride.[56]

## EM Has Authorized Selling Hydrofluoric Acid and Applying Proceeds of the Sales to Contract Costs

EM manages the other primary product of the conversion process, hydrofluoric acid, by selling it to a private company. Hydrofluoric acid is a highly corrosive product with multiple industrial uses, including glass etching. EM has authorized its contractor for the DUF6 conversion

[53]According to EM officials, DU oxide is normally loaded into cylinders. However, some DU oxide is also loaded into 55-gallon drums to be used as needed. EM sent two of these drums to Y-12.

[54]NNSA is constructing the Uranium Processing Facility to relocate key uranium processing equipment and capabilities into a new, multiple building complex. The facility will consist of processing capabilities for enriched uranium casting, oxide production, and salvage and accountability operations to support the nuclear weapons stockpile, defense nuclear nonproliferation, and naval reactors.

[55]According to the supplemental environmental impact statement, heel cylinders contain approximately 50 pounds of residual nonvolatile material left after the DUF6 has been removed. Empty cylinders have had the DUF6 and heel material removed and contain limited residual material.

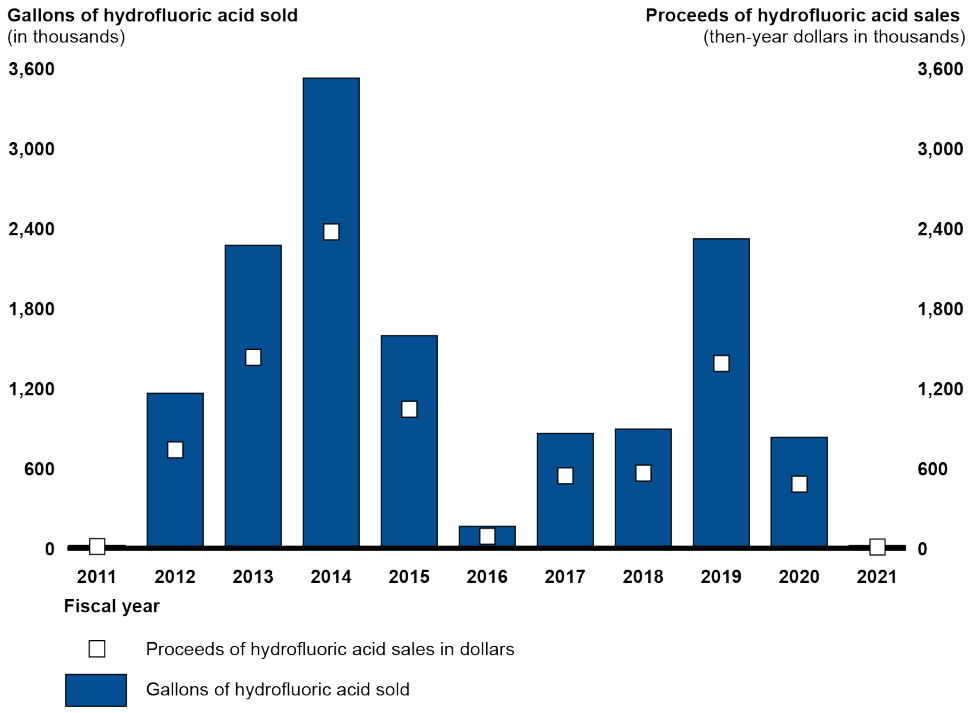
[56]The supplemental environmental impact statement noted that disposal of calcium fluoride would only occur if EM could not find a beneficial way to reuse the material. According to EM officials, calcium fluoride can be used commercially to make concrete. EM officials said that they have reached out to several companies about purchasing EM's calcium fluoride, but they have not received any interest.

facilities to sell hydrofluoric acid on DOE's behalf. EM gave this direction to the first contractor for the facilities, which signed an agreement to sell hydrofluoric acid to a private company in May 2006. That agreement has transferred to each subsequent contractor for the facilities, including the current contractor.

According to officials, EM has also authorized its contractor to keep the proceeds of sales of hydrofluoric acid to offset the cost of the contract to operate the facilities. The first sales agreement was signed in 2006, but hydrofluoric acid sales did not begin until 2011, after both conversion facilities began operations. According to contractor data provided by EM, EM's contractors sold about 13.7 million gallons of hydrofluoric acid from fiscal year 2011 through 2021, for proceeds that ranged from about $9,000 in fiscal year 2021 to about $2.4 million in fiscal year 2014. EM has been able to keep and use the proceeds of the hydrofluoric acid sales under appropriations laws enacted from fiscal years 2011 through 2022.[57] See figure 8 below for a breakdown of these amounts by fiscal year.

[57]EM officials told us that they can authorize their contractor to keep and use the proceeds of the hydrofluoric acid sales to offset their contract costs under a 2002 appropriations law that allows agencies to retain proceeds of sales of property related to waste prevention and recycling programs. Treasury and General Government Appropriations Act, 2002, Pub. L. No. 107-67, § 607, 115 Stat. 515, 546 and 41 C.F.R. § 102-38.295. We note that similar language has been repeated in appropriations law from fiscal year 2011—the first year of hydrofluoric acid sales—through fiscal year 2022.

**Figure 8: Amounts Sold and Proceeds of Sales of Hydrofluoric Acid, 2011-2021**




Source: GAO analysis of Department of Energy information. | GAO-105471

## Accessible Data Table for Figure 8

| | Gallons of hydrofluoric acid sold | Proceeds of hydrofluoric acid sales |
|---|---|---|
| 2011 | 22 | 13 |
| 2012 | 1,162 | 738 |
| 2013 | 2,272 | 1431 |
| 2014 | 3,527 | 2372 |
| 2015 | 1,595 | 1043 |
| 2016 | 165 | 90 |
| 2017 | 862 | 543 |
| 2018 | 894 | 564 |
| 2019 | 2,320 | 1386 |
| 2020 | 833 | 481 |
| 2021 | 21 | 9 |

## Conclusions

As of January 2022, EM estimates that the Portsmouth facility will operate until 2036 and the Paducah facility until 2054 in order to process the approximately 60,000 cylinders of DUF6 remaining to be converted to DU oxide for disposal. EM's schedule estimates do not account for the 19-27 months that the facilities were not operating during and after the COVID-19 shutdown; and, as of July 2022, EM is recalculating the facilities' cost and schedule estimates. EM has three agreements in place that might allow it to transfer up to 30,000 cylinders to other entities. By transferring portions of the inventory to these other entities—including selling DUF6 to a private company—EM would reduce the amount of DUF6 it would have to convert. This could reduce its operating time for the two conversion facilities by up to 30 years and potentially save over $2 billion in operating costs. However, as we have previously reported, we believe that DOE's authority to sell depleted uranium is doubtful. Legislation that establishes both DOE's authority to sell depleted uranium and any conditions for such sales, along the lines of those for the sale of other types of uranium in the government's inventory, could help ensure that EM will be able to sell some of its DUF6 and that such sales would not potentially harm the uranium industry.

## Matter for Congressional Consideration

Congress should consider enacting legislation to clarify DOE's authority to sell depleted uranium, including any conditions connected to such sales. (Matter for Consideration 1)

## Agency Comments

We provided a draft of this report to DOE for review and comment. DOE officials told us that they had no formal comments on the draft report. DOE provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Energy, and other interested parties. In addition, this report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or andersonn@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.

Nathan Anderson
Director, Natural Resources and Environment

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# Appendix I: Forms of Depleted Uranium

Depleted uranium is a by-product of the uranium enrichment process. During the enrichment process, natural uranium is enriched by separating uranium-235 from uranium-238 to increase the concentration of uranium-235 in some material. The rest of the material is called “depleted uranium” because it has a lower concentration of uranium-235 than the 0.7 percent contained in natural uranium. There are several forms of depleted uranium, including those described in table 1 below.

**Table 1: Select Depleted Uranium Forms and Descriptions**

| Form | Description |
|---|---|
| Depleted uranium hexafluoride (DUF6) | DUF6 is also known as “tails.” DUF6 is the initial by-product of the enrichment process. DUF6 is highly corrosive and dangerous to the environment and human health. DUF6 can be converted into other forms of depleted uranium, depending on need. |
| Depleted uranium tetrafluoride (DUF4) | DUF4 is also known as “green salt.” Historically, the Department of Energy (DOE) or its contractors have converted DUF6 into DUF4 through a chemical process involving hydrogen. DUF4 can then be converted into a metal form through a chemical process known as the Ames process. |
| Depleted uranium oxide (DU oxide) | DU oxide is a more stable form of depleted uranium than DUF6 that can be permanently disposed of as waste. |

Source: GAO. | GAO-22-105471

# Appendix II: GAO Contact and Staff Acknowledgments

## GAO Contact

Nathan Anderson at (202) 512-3841 or andersonn@gao.gov.

## Staff Acknowledgments

In addition to the contact named above, Amanda K. Kolling (Assistant Director), Kelly Butler (Analyst-in-Charge), Mark Braza, Antoinette Capaccio, Claudia Hadjigeorgiou, Gwen Kirby, Sara Sullivan, and Rachel Whitaker made key contributions to this report.

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