
Department of Energy Management of Depleted Uranium

Briefing for Congressional Staff

Senate Energy and Natural Resources Committee
House Energy and Commerce Committee
House Subcommittee on Oversight and Investigations,
Committee on Energy and Commerce

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Overview

- Background
- Objectives, Scope, and Methodology
- Department of Energy's (DOE) Options for its Depleted Uranium Tails
- GAO's Estimate of the Tails' Value
- Conclusions and Recommendations

Background

- DOE's and its predecessor agencies' enrichment of natural uranium since the 1940s has left it with a legacy of about 700,000 metric tons of depleted uranium hexafluoride—the leftover “tails” remaining from the enrichment process
- DOE stores this material in about 63,000 metal cylinders at its Paducah, Kentucky and Portsmouth, Ohio gaseous diffusion plants
- Uranium hexafluoride must be safely stored because the material is radioactive and forms extremely corrosive and potentially lethal compounds if it contacts water
- DOE spends about \$4 million annually to maintain these cylinders

Background

- Tails have historically been considered as a waste product and economic and environmental liability because considerable enrichment would be required to extract the remaining relatively small amounts of useful uranium-235
- However, the recent approximately tenfold increase in uranium prices means that much of DOE's inventory of tails could potentially be re-enriched profitably
- DOE also maintains large inventories of natural and enriched uranium that are also surplus to the department's needs
- Any plan to beneficially use DOE's tails must also be reconciled with the department's plans for its other surplus uranium inventories

Objectives

1. What are DOE's potential options for reusing or indefinitely storing its tails?
 2. What is the potential value of DOE's tails and what factors affect that value?
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Scope and Methodology

To conduct this work, we have:

- Reviewed DOE's draft uranium management plan, depleted uranium inventory summary, and potential valuations
- Reviewed proposals for the inventory from USEC and others, and interviewed 10 U.S. nuclear power utilities, enrichment services companies, and others in the industry regarding their commercial interests in the inventory
- Interviewed officials from DOE's Office of Nuclear Energy and Office of Environmental Management, USEC, and the Paducah plant union
- Estimated the potential value based on DOE data on its depleted uranium inventory and obtained USEC's analyses of re-enrichment scenarios
- Been reviewing legal issues regarding DOE's ability to manage its depleted uranium

We conducted this performance audit from July 2007 to March 2008 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.

Objective 1: DOE Has Three Potential Options for Its Tails

1. DOE could try to sell the tails “as is;”
 2. It could arrange for the re-enrichment of the tails into a more valuable form; or
 3. It could store the tails indefinitely pending permanent disposition
- However, DOE has not finished a comprehensive assessment of these options

DOE's Authority to Sell the Tails "As Is" is Doubtful

- Specific statutory language in the USEC Privatization Act of 1996 that governs DOE's disposition of its uranium may limit DOE's ability to sell or transfer depleted uranium
 - Specifically, section 3112 of the Act explicitly bars DOE from selling or transferring "any uranium" except as consistent with the section
 - Section 3112 then specifies conditions for DOE's sale or transfer of natural and enriched uranium of various types
 - Nowhere, however, does section 3112 provide conditions for DOE to sell or transfer depleted uranium

Industry Concerns About Purchasing Tails

- Individual utilities were often interested only in limited quantities of DOE's tails because they had existing uranium inventories or were concerned about depending upon a single source to fulfill all of their requirements
- Buyers would discount, perhaps steeply, their offered prices to make buying tails attractive compared with purchasing natural uranium on the open market
- Risks utilities identified:
 - Obtaining sufficient enrichment services—would likely require new enrichment contracts at potentially high prices
 - Ensuring the tails were free of contaminants
 - Ensuring the cylinders containing the tails could be safely transported

DOE Could Have the Tails Re-Enriched

- Although DOE's legal authority to sell the tails in their current form is doubtful, DOE has the general legal option to contract for enrichment services commercially and sell the resulting natural or enriched uranium
- DOE would have to pay for re-enrichment, however, it may obtain more value from selling re-enriched uranium instead of the tails if its re-enrichment costs were less than the discount it would have to offer utilities
- Several enrichment firms are interested in working with DOE:
 - USEC
 - LES
 - AREVA
 - Global Nuclear Fuel

DOE Could Store the Tails Indefinitely

- In the late 1990s, when relatively low uranium prices meant that tails were viewed as waste, DOE developed a plan for the safe, long-term storage of the material
- DOE is constructing facilities at Paducah and Portsmouth to chemically convert its tails into a more stable compound that is suitable for long-term storage
- Storing the tails indefinitely could prevent DOE from taking advantage of the large increase in uranium prices
- DOE would also continue to incur costs associated with storing and maintaining uranium cylinders
- Once converted, DOE could later change the tails back into uranium hexafluoride for re-enrichment, but would incur additional costs to do so (about \$9/kgU)
- Even if DOE sells or re-enriches some of its tails, conversion will still be necessary for the approximately two-thirds of DOE's tails that are not economical to re-enrich

DOE Lacks a Comprehensive Assessment of Its Options for the Tails

- DOE has been developing a plan since 2005 to sell excess uranium from across its inventories of depleted, natural, and enriched uranium
- In March 2008, DOE issued a policy statement that established a general framework for how DOE plans to manage its uranium inventories
- The policy statement also established a cap on the total annual sales of uranium
 - The cap was set at 10 percent of U.S. requirements for uranium
- DOE's March 2008 policy statement lacks specific information on the types and quantities of uranium that the department manages
- It does not discuss whether it would be more advantageous to sell or re-enrich tails
- It lacks milestones for determining when any sales or re-enrichment decisions will be made, stating only that this effort will occur "in the near future"

Objective 2: GAO's Estimate of the Tails' Value

- To estimate the potential value of DOE's tails, we developed a model using standard formulas for the amounts of enriched uranium and tails produced from given quantities of uranium and enrichment services
- Using data from DOE on the quantities and assays of tails in its inventory and February 2008 published market prices of \$200 per kilogram of uranium as uranium hexafluoride and \$145 per separative work unit (SWU), we calculated the net value of DOE's tails as \$7.6 billion
- However, this estimate is very sensitive to changing uranium prices as well as to the availability of sufficient enrichment capacity

GAO's Tails Valuation Model

1. For a given assay, calculate how much depleted uranium feed would be required to produce one kilogram of “natural uranium” (0.711% assay) product at the optimal residual tails assay
2. Using DOE’s inventory data for each assay level, calculate how much natural uranium would be produced by re-enriching the material to 0.711% assay
3. Calculate how much “further” depleted uranium would be left over (“residual tails”)
4. Calculate how much enrichment (SWU) would be required
5. Using February 2008 market price of \$200 per kilogram of uranium, calculate the value of the 0.711% assay uranium produced
6. Using February 2008 market price of \$145 per SWU, calculate the cost of the SWU
7. Using DOE-supplied cost of about \$5.92 per kilogram of uranium, calculate the cost savings resulting from not having to convert re-enriched tails
8. Repeat for each assay in DOE’s inventory

EXAMPLE: GAO's Tails Valuation Model Using 0.35% Assay Depleted Uranium Feed and 0.18% Residual Tails

1. 3.124 kgU of 0.35% assay depleted uranium feed are required to produce 1 kg of 0.711% assay natural uranium product
2. DOE inventory of approx. 97 million kgU 0.35% assay uranium, when re-enriched, would produce about 31 million kg of 0.711% assay uranium
3. 66 million kgU (97 million kgU feed minus 31 million kgU product) 0.18% assay residual tails left over
4. 22 million SWU are required
5. Value of 31 million kgU natural uranium=\$6.2 billion
6. Cost of 22 million SWU=\$3.2 billion
7. Cost savings of not converting 31 million kgU of tails=\$184 million

NET VALUE OF 0.35 ASSAY DEPLETED URANIUM=\$3.2 BILLION

REPEAT FOR EACH ASSAY IN DOE'S INVENTORY

Totals from GAO's Tails Valuation Model

Tails processed (0.23% to 0.65% assay)	420 million kgU (621 million kg DUF ₆)
Natural uranium produced (0.711% assay)	90 million kgU
Residual tails remaining (0.18% assay)	330 million kgU
Enrichment services required	75.3 million SWU
Value of uranium produced (\$200/kgU as UF₆)	\$17.9 billion
Cost of SWU (\$145/SWU)	\$10.9 billion
Cost savings from not converting re-enriched tails	\$531 million
NET VALUE	\$7.6 billion

Sensitivity of the Tails' Value to Changing Uranium Prices

Uranium price (\$/kgU as UF6)	Optimal residual tails assay	Tails re-enriched (kgU)	Lowest assay re-enriched	Natural uranium produced (kgU)	SWU required	Natural uranium value	SWU cost (\$145/SWU)	Conversion cost savings	Net value
\$350	0.14%	492,020,279	0.15%	117,245,661	129,889,890	\$41,035,981,352	\$18,834,034,018	\$693,639,400	\$22,895,586,734
\$325	0.15%	491,948,013	0.18%	110,565,187	114,352,438	\$35,933,685,623	\$16,581,103,480	\$654,116,911	\$20,006,699,055
\$300	0.15%	491,948,013	0.18%	110,565,187	114,352,438	\$33,169,555,960	\$16,581,103,480	\$654,116,911	\$17,242,569,391
\$275	0.16%	491,948,013	0.18%	103,643,538	99,988,900	\$28,501,972,988	\$14,498,390,562	\$613,167,609	\$14,616,750,036
\$250	0.17%	491,948,013	0.18%	96,466,006	86,647,199	\$24,116,501,564	\$12,563,843,843	\$570,704,469	\$12,123,362,190
\$225	0.18%	420,183,251	0.23%	89,693,885	75,303,919	\$20,181,124,180	\$10,919,068,256	\$530,639,788	\$9,792,695,712
\$200	0.18%	420,183,251	0.23%	89,693,885	75,303,919	\$17,938,777,049	\$10,919,068,256	\$530,639,788	\$7,550,348,581
\$175	0.20%	420,183,251	0.23%	76,758,881	56,781,097	\$13,432,804,125	\$8,233,258,995	\$454,114,749	\$5,653,659,879
\$150	0.22%	420,183,251	0.23%	62,770,108	40,355,772	\$9,415,516,199	\$5,851,586,944	\$371,355,491	\$3,935,284,746
\$125	0.24%	316,772,394	0.28%	50,886,668	28,759,426	\$6,360,833,562	\$4,170,116,777	\$301,051,637	\$2,491,768,421
\$100	0.26%	316,772,394	0.28%	39,095,727	19,271,896	\$3,909,572,723	\$2,794,424,966	\$231,295,014	\$1,346,442,770
\$75	0.29%	175,813,358	0.31%	24,331,085	9,604,705	\$1,824,831,360	\$1,392,682,211	\$143,945,617	\$576,094,766
\$50	0.34%	123,155,853	0.35%	7,955,535	2,139,971	\$397,776,735	\$310,295,825	\$47,065,898	\$134,546,807
\$25	0.40%	15,930,607	0.41%	1,783,569	268,744	\$44,589,224	\$38,967,930	\$10,551,808	\$16,173,102

Note: Assumes \$145 per separative work unit (SWU)

Sensitivity of the Tails' Value to Changing Enrichment Costs

SWU price (\$/SWU)	Optimal residual tails assay	Tails re-enriched (kgU)	Lowest assay re-enriched	Natural uranium produced (kgU)	SWU required	Natural uranium value (\$200/kgU)	SWU cost	Conversion cost savings	Net value
\$250	0.25%	316,772,394	0.28%	45,119,082	23,899,975	\$9,023,816,451	\$5,974,993,781	\$266,929,905	\$3,315,752,575
\$240	0.24%	316,772,394	0.28%	50,886,668	28,759,426	\$10,177,333,699	\$6,902,262,252	\$301,051,637	\$3,576,123,083
\$230	0.24%	316,772,394	0.28%	50,886,668	28,759,426	\$10,177,333,699	\$6,614,667,992	\$301,051,637	\$3,863,717,344
\$220	0.23%	316,772,394	0.28%	56,414,438	33,871,402	\$11,282,887,651	\$7,451,708,459	\$333,754,586	\$4,164,933,779
\$210	0.23%	316,772,394	0.28%	56,414,438	33,871,402	\$11,282,887,651	\$7,112,994,438	\$333,754,586	\$4,503,647,799
\$200	0.22%	316,772,394	0.28%	61,717,044	39,259,980	\$12,343,408,855	\$7,851,995,949	\$365,125,440	\$4,856,538,347
\$190	0.22%	420,183,251	0.23%	62,770,108	40,355,772	\$12,554,021,599	\$7,667,596,686	\$371,355,491	\$5,257,780,405
\$180	0.21%	420,183,251	0.23%	69,904,103	48,333,093	\$13,980,820,573	\$8,699,956,726	\$413,561,061	\$5,694,424,908
\$170	0.21%	420,183,251	0.23%	69,904,103	48,333,093	\$13,980,820,573	\$8,216,625,797	\$413,561,061	\$6,177,755,837
\$160	0.20%	420,183,251	0.23%	76,758,881	56,781,097	\$15,351,776,143	\$9,084,975,443	\$454,114,749	\$6,720,915,449
\$150	0.19%	420,183,251	0.23%	83,350,519	65,751,317	\$16,670,103,860	\$9,862,697,490	\$493,111,674	\$7,300,518,044
\$145	0.18%	420,183,251	0.23%	89,693,885	75,303,919	\$17,938,777,049	\$10,919,068,256	\$530,639,788	\$7,550,348,581
\$140	0.18%	420,183,251	0.23%	89,693,885	75,303,919	\$17,938,777,049	\$10,542,548,661	\$530,639,788	\$7,926,868,176
\$130	0.18%	420,183,251	0.23%	89,693,885	75,303,919	\$17,938,777,049	\$9,789,509,471	\$530,639,788	\$8,679,907,366
\$120	0.17%	491,948,013	0.18%	96,466,006	86,647,199	\$19,293,201,251	\$10,397,663,870	\$570,704,469	\$9,466,241,850
\$110	0.16%	491,948,013	0.18%	103,643,538	99,988,900	\$20,728,707,628	\$10,998,779,047	\$613,167,609	\$10,343,096,190
\$100	0.16%	491,948,013	0.18%	103,643,538	99,988,900	\$20,728,707,628	\$9,998,890,042	\$613,167,609	\$11,342,985,194
\$90	0.15%	491,948,013	0.18%	109,884,146	112,866,088	\$21,976,829,154	\$10,157,947,919	\$650,087,792	\$12,468,969,028
\$80	0.14%	492,020,279	0.15%	117,245,661	129,889,890	\$23,449,132,201	\$10,391,191,182	\$693,639,400	\$13,751,580,419
\$70	0.13%	492,020,279	0.15%	123,696,171	146,781,782	\$24,739,234,157	\$10,274,724,736	\$731,801,390	\$15,196,310,811

Note: Assumes \$200 per kilogram of uranium as uranium hexafluoride

Factors Affecting the Tails' Value

- As the previous two slides demonstrate, the value of the tails is extremely sensitive to changing uranium and SWU prices
- Published SWU prices have been rising steadily over the past eight years
- However, published uranium prices have been extremely volatile, ranging from a low of \$21 per kilogram of uranium as uranium hexafluoride in November 2000 to a high of about \$350 per kilogram in July 2007
- Substituting these values into our model results in a range of values from almost nothing to more than \$20 billion
- Accordingly, the actual amount of revenue that DOE could obtain could be much higher or lower than our \$7.6 billion estimate depending upon uranium prices at the time the material is marketed and DOE's ability to obtain sufficient enrichment services, as well as the price of those services

Conclusions

- Recent dramatic increases in uranium prices give the U.S. government a chance to gain some benefit from material once considered a liability
- Under current law, however, one potential avenue—sale of the tails in its current form—is likely closed to DOE
- Obtaining legal authority from Congress to sell depleted uranium would provide DOE with an additional option in determining the best course of action to obtain the maximum value for its tails
- Unfortunately, DOE has not completed a comprehensive assessment of its options with sufficient speed to take advantage of current market conditions
- DOE's March 2008 policy statement lacks the detailed information on which to base a decision
- It is important for DOE to complete a comprehensive uranium management assessment that details the department's options, its authority to implement these options, and the impact of these options on the domestic uranium industry

Recommendations

Matter for Congressional Consideration

- Congress should consider clarifying DOE's statutory authority to manage depleted uranium, under the USEC Privatization Act or other legislation, including explicit direction about whether and how DOE may sell or transfer the tails in their current form

Recommendations for Executive Action

- DOE should complete a comprehensive uranium management assessment as soon as possible. The assessment should contain:
 - Detailed information on the types and quantities of depleted, natural, and enriched uranium DOE currently manages;
 - An assessment of DOE's options for this material;
 - Details on DOE's legal authority to implement these options;
 - An analysis of the impact of each of these options on the domestic uranium industry; and
 - Details on how implementation of any of these options should be adjusted in the event that market conditions change