DEPLETED URANIUM HEXAFLUORIDE MANAGEMENT PROGRAM

SUMMARY OF THE TECHNOLOGY ASSESSMENT REPORT FOR THE LONG-TERM MANAGEMENT OF DEPLETED URANIUM HEXAFLUORIDE

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Prepared for the Department of Energy by
Lawrence Livermore National Laboratory
and
Science Applications International Corporation

SUMMARY OF THE TECHNOLOGY ASSESSMENT REPORT FOR THE LONG-TERM MANAGEMENT OF DEPLETED URANIUM HEXAFLUORIDE

INTRODUCTION

The *Technology Assessment Report for the Long-Term Management of Depleted Uranium Hexafluoride* assesses recommendations from interested persons, industry, and government agencies for potential uses for the depleted uranium hexafluoride (UF_6) stored at the gaseous diffusion plants, and evaluates technologies that could facilitate the long-term management of this material. This *Summary of the Technology Assessment Report for the Long-Term Management of Depleted Uranium Hexafluoride* provides an overview of the technology assessment process rather than a comprehensive analysis. For more detailed information, the reader should refer to the complete two-volume report, dated June 30, 1995, which is available at the public information centers for each of the gaseous diffusion plants and at the Department of Energy (DOE) Headquarters Freedom of Information reading room in Washington, D.C. The report is also available from the National Technical Information Service, Springfield, VA, 22161 (telephone: 703-487-4690) by ordering UCRL-AR-120372, Volumes I and II.

BACKGROUND

Approximately 560,000 metric tons of depleted UF_6 have accumulated at the three gaseous diffusion plants located in Oak Ridge, Tennessee, Paducah, Kentucky, and Portsmouth, Ohio. The U.S. Department of Energy operated the plants from 1945 until July 1, 1993, at which time the Paducah and Portsmouth plants were leased to the United States Enrichment Corporation (USEC), as required by the Energy Policy Act of 1992. All diffusion operations at the Oak Ridge plant ceased in 1985. DOE is responsible for all the depleted UF_6 which accumulated before July 1, 1993.

Depleted UF_6 is stored as a solid in a partial vacuum in 10- to 14-ton steel cylinders. Most of which are about 12 ft long and 4 ft in diameter. The approximately 47,000 cylinders are currently distributed as follows: 29,000 at Paducah, 13,000 at Portsmouth, and 5,000 at Oak Ridge (K-25 Site). The cylinders are stacked two high, resting on concrete or wooden storage chocks, in outdoor gravel, asphalt, or concrete storage yards. Cylinders are regularly inspected, and corrective maintenance activities such as restacking cylinders, lining or replacing wooden storage chocks (which can contribute to corrosion by retaining water), and replacing or refurbishing cylinders are performed as needed.

RATIONALE FOR DEVELOPING THE DEPLETED URANIUM HEXAFLUORIDE MANAGEMENT PROGRAM

The goal of the Depleted Uranium Hexafluoride Management Program is to select and implement a long-term management strategy for DOE's depleted UF_6. The need for such a strategy stems from questions that have arisen due to the change in the mission of DOE programs for nuclear materials production and research. These changes have been brought about by the end of the Cold War, by the shift in emphasis mandated by the President's budget requests, and by directives from the Secretary of Energy to reconsider present and future DOE responsibilities.

The unique properties of depleted UF_6, as well as the large volumes in storage, suggest that the evaluation, analysis, and decisions on the fate of this material be separate from those for other DOE materials that are in storage or awaiting disposition. The Department has determined that this is a major federal action with potentially significant environmental impacts and therefore requires the preparation of an environmental impact statement (EIS), in accordance with the National Environmental Policy Act (NEPA) of 1969.

OVERVIEW OF THE DEPLETED URANIUM HEXAFLUORIDE MANAGEMENT PROGRAM

The first phase of the Depleted Uranium Hexafluoride Management Program—management strategy selection—consists of several elements: Engineering Analysis (including Technology Assessment), Cost Analysis, and preparation of an EIS. The relationship among these program elements is shown in Figure 1. Lawrence Livermore National Laboratory (LLNL)/Science Applications International Corporation (SAIC) has been tasked by DOE to conduct the Engineering and Cost Analysis Projects, while Argonne National Laboratory (ANL) is developing the EIS.

Technology Assessment is the first major component of the program and is the precursor to the Engineering Analysis Project. The goal of Technology Assessment is to identify and assess the options to be considered in selecting the optimum long-term management strategy for depleted UF_6. The *Technology Assessment Report*, dated June 30, 1995, completes the Technology Assessment phase of the program. The report provides an overview of Technology Assessment, a summary of responses received to the Request for Recommendations (November 10, 1994, 59 FR 56324), and the evaluations by the Independent Technical Reviewers who assessed the technical feasibility of the responses and five other options under consideration by DOE.

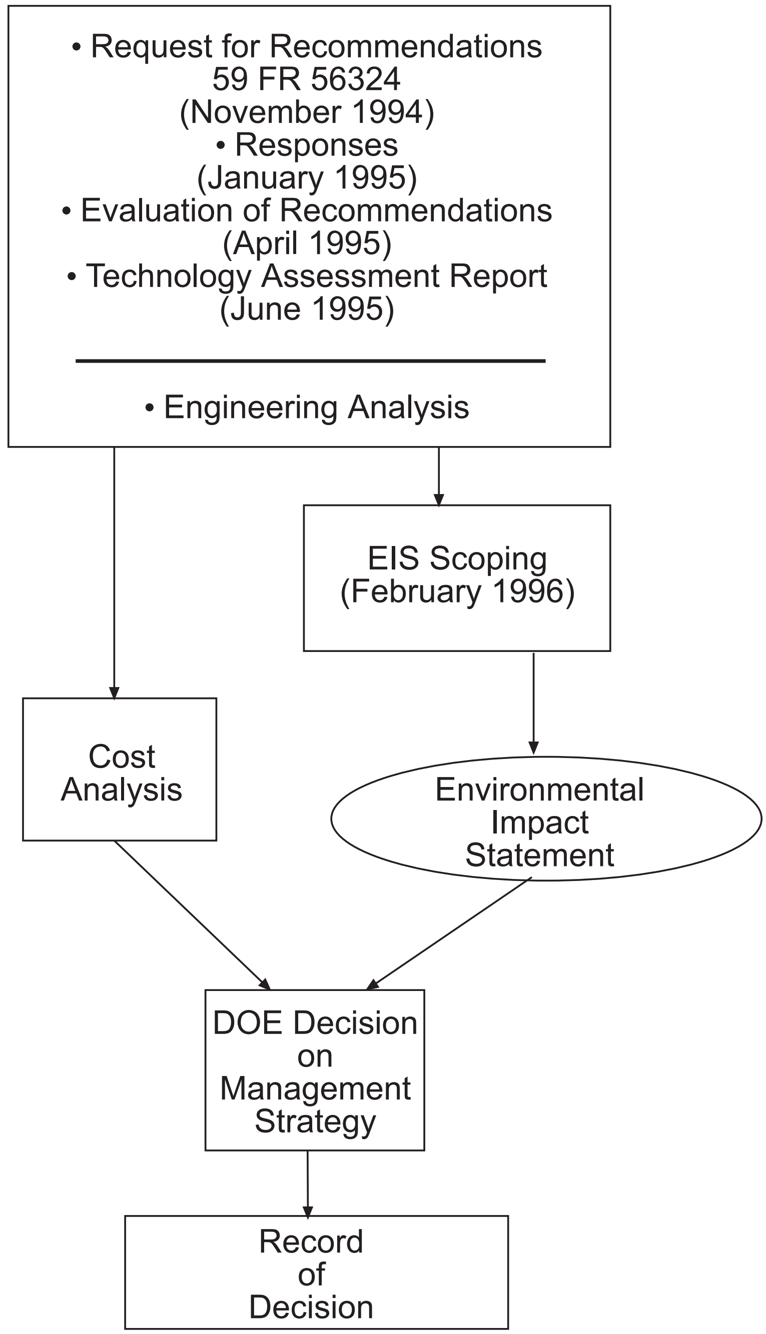
The **Engineering Analysis Project** will provide a comprehensive technical analysis of the technology options that will form the basis for the long-term management strategy alternatives. This project will provide the engineering data necessary to describe each option and determine environmental impacts in the EIS.

The **Cost Analysis Project** will estimate the costs associated with each of the options considered for the long-term management of depleted UF_6, using the information from the Engineering Analysis Project. Estimated costs will include a breakdown of capital, operations and maintenance, waste processing and disposal, decommissioning, and environmental restoration (if applicable). Variations to time/schedule, escalation and discount rates, disposal costs, and throughput will be evaluated.

The **EIS** will assess the potential environmental impacts of the alternative strategies for the long-term management of depleted UF_6. These general strategy alternatives will be combinations of the various options related to depleted UF_6: conversion, transportation, reuse, storage, and disposal. The specific process(es) and site(s) for conversion, manufacturing, disposal, or storage will be determined in the second (or implementation) phase of the Depleted Uranium Hexafluoride Management Program. Additional NEPA documents will be prepared as necessary.

Public Participation is an essential part of the Depleted Uranium Hexafluoride Management Program. The intent is to provide multiple opportunities for public involvement in the DOE decision-making process and ensure two-way communication between DOE and its stakeholders. A stakeholder, in this case, is any person or organization who is interested in and/or potentially affected by the Department's activities and decisions concerning the management of depleted UF_6, or who is interested in the associated issues of potential technologies, environmental protection, and safety and health. A stakeholder list was compiled specifically for this program with input from DOE Headquarters, public outreach personnel at the three gaseous diffusion plants, attendance lists from public forums, and responses to the November 10, 1994, Request for Recommendations.

Figure 1 - Elements of the Depleted Uranium Hexafluoride Management Program



MANAGEMENT STRATEGY SELECTION AND IMPLEMENTATION

When selecting a long-term management strategy for depleted UF_6, the Department will consider the analysis in the environmental impact statement, along with the life cycle costs of each of the alternatives discussed in the EIS. The management strategy selection phase will culminate in a Record of Decision (ROD), which will identify the DOE's preferred strategy and provide the rationale and supporting documentation. The second phase of the program will focus on implementation of the management strategy. This phase will involve the selection of specific technologies and uses, and specific site(s) where implementation would occur. It is likely that, as part of this phase, DOE will issue a request for proposals pertaining to the selected technologies and uses. Implementation will include the preparation of NEPA documentation for any facility(ies) involved in the strategy selected.

TECHNOLOGY ASSESSMENT REPORT

DOE formally initiated its Depleted Uranium Hexafluoride Management Program with the publication of a Request for Recommendations and an Advance Notice of Intent in the November 10, 1994, *Federal Register*. This request was made to help ensure that, by seeking as many recommendations as possible, Department management would consider a wide variety of reasonable options for the long-range management strategy.

The *Technology Assessment Report* discusses seventy options, suggested in 57 responses to the Request for Recommendations (several responses contained more than one recommendation), including five options that DOE was already considering but which were not suggested in any of the responses received. Eleven of the 57 responses contained proprietary information and were handled confidentially. However, most of these were released or re-written for release by the submitters at the conclusion of the technology assessment process (three submittals remain proprietary and are discussed in a separate proprietary addendum to the *Technology Assessment Report*).

Responses were evaluated by five Independent Technical Reviewers (see Table 1), working separately from each other. These reviewers were selected for their experience and expertise in specific technical areas from more than 40 candidates submitted to LLNL/SAIC for consideration.

Table 1
Independent Technical Reviewers

Ms. Mary Glass
Mr. Brian Hajek
Dr. Walter Loewenstein
Mr. Loring Mills
Mr. Henry Morton

Evaluation factors for use by the reviewers were compiled and submitted to the public for comment. Forty-one comments were received and considered in developing the final list (these comments are included in the *Technology Assessment Report*). The resulting evaluation factors, as they were given to the reviewers, are presented in Table 2.

Table 2
Evaluation Factors

Environment, Safety, and Health. Consider the following issues of concern to workers, the public, and the environment:

- *Issues that may arise as a result of operations, transportation, handling, storage, and disposal, including effluents and emissions.*

- *Issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*

- *Design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

Waste Management. While this factor might well be included in the Environment, Safety, and Health factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed, or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*

- *Potential for waste minimization in use or manufacture.*

- *Potential for recycling.*

Continued on next page

Table 2 (continued)

Costs. Consider costs that are associated with the development or use of a technology or product, or that could preclude consideration of a recommendation.

- *Capital costs, both initial (including research and development) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any by-products.*

Technical Maturity. For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design—conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

Socioeconomics. Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

Other Factors. Add any other information believed pertinent to the feasibility of the submission.

In addition to evaluating the responses against these factors, the Independent Technical Reviewers were asked to conclude their evaluations with a determination as to whether or not the option was reasonable and to provide a brief justification for their conclusion. The terms "reasonable" and "feasible" were used more or less interchangeably by the Reviewers. Ultimately, DOE will determine what options are "reasonable" for inclusion in further engineering analyses and "reasonable" for the purposes of NEPA. The Reviewers' verbatim evaluations are included in the *Technology Assessment Report*.

Several recommendations were received late and were reviewed by technical LLNL/SAIC staff according to the same evaluation factors. All responses received were reviewed either by the Independent Technical Reviewers or by LLNL/SAIC.

Table 3 presents a summary of the feasibility analysis, based on the Independent Technical Reviewers' and LLNL/SAIC's evaluations. The table identifies the document number and the respondent, briefly describes the recommendation, and indicates whether the analysis concluded that the recommendation be considered feasible, feasible with qualifiers, or not feasible. In the latter two cases, the qualifiers or the reasons for the infeasibility determination are briefly summarized.

Table 3
Depleted Uranium Hexafluoride Management Program
Responses to Request for Recommendations (59 FR 56324)

Summary of Feasibility

Doc. No.	Respondent	Summary of Recommendation(s)	Feasible	Not Feasible
1	Mr. A.N. Tschaeche Idaho Falls, Idaho	Recommends depleted UF_6 remain in its current form, at its present location, and that it be used to make blanket material for breeder reactors.	• (with qualifier -- implementation of breeder reactors is tentative and, if employed, likely to occur beyond 2020)	
2	Mr. Mark Strauch Livermore, California	Contains four recommendations: (Option 2-1) retention of enough depleted uranium as UF_6 to blend down the highly enriched uranium from retired nuclear weapons; (Option 2-2) retention of enough depleted uranium as UF_6 to blend down the highly enriched uranium from the former Soviet Union; (Option 2-3) use of depleted uranium in a Multi-Purpose Canister (MPC); and (Option 2-4) reduction of UF_6 to a metal.	2-1 • 2-2 • 2-3 • 2-4 •	
3	Mr. Peter Lenny Cameco Canada	See Document No. 35	See Document No. 35	
4	Mr. Bert Jody, Jr. Davis Transport Paducah, Kentucky	Recommends (Option 4-1) reduction to oxide and (Option 4-2) reduction to metal.	4-1 • 4-2 •	
5	Mr. William Quapp Idaho National Engineering Laboratory Idaho Falls, Idaho	Recommends (Option 5-1) use of UF_6 to produce DUCRETE; (Option 5-2) conversion to metal for use in energy storage flywheels;(Option 5-3) conversion to metal using a plasma process; and (Option 5-4) a conversion process developed by INEL to support DUCRETE efforts.	5-1 • 5-2 • 5-3 • 5-4 •	
6	Mr. William Bear Siemens Power Corporation Bellevue, Washington	Recommends patented dry conversion process to produce uranium oxide.	•	
7	Mr. Harry A. Nesteruk M4 Environmental Management, Inc. Oak Ridge, Tennessee	Proprietary - See Document No. 29	See Document No. 29	

Doc. No.	Respondent	Summary of Recommendation(s)	Feasible	Not Feasible
8	Mr. Dennis Wright	Recommends use of a titan missile or space shuttle to send depleted UF_6 to the sun.		• (unacceptably high environmental safety and health risks)
9	Mr. Frank Warner General Atomics San Diego, California Mr. Sanford Rock Allied Signal, Inc. Morristown, New Jersey	Recommends conversion of depleted UF_6 to triuranium octaoxide (U_3O_8) using a General Atomics patented process producing anhydrous hydrogen fluoride (AHF).	•	
10	Mr. Frank A. Shallo COGEMA, Inc. Bethesda, Maryland	Construction and operation of a conversion facility for long-term storage of U_3O_8, recycling hydrofluoric acid.	•	
11	Mr. A.N. Tschaeche Idaho Falls, Idaho	Use of depleted UF_6 in breeder reactors to generate electricity.	See Document No. 1	
12	Mr. Dennis R. Floyd Manufacturing Sciences Corporation Denver, Colorado	Direct reduction of UF_6 to metal, by-passing the uranium tetrafluoride (UF_4) stage, by using a technique involving reduction by hydrogen in a high-temperature plasma.	• with qualifier -- further development on plasma technology required	
13	Mr. Patrick F. Brown Oak Ridge, Tennessee	(Option 13-1) conversion of depleted UF_6 to fluorine compounds; (Option 13-2) storage of the oxide in steel boxes made from the depleted UF_6 cylinders; and (Option 13-3) recovery of ^{235}U for value as separative work units and or ^{238}U for use in breeder reactors.	13-1 • 13-2 • 13-3 • (with qualifier -- implementation of breeder reactors is tentative and, if employed, likely to occur beyond 2020)	
14	Mr. Alan Waltar American Nuclear Society La Grange Park, Illinois	Continue present mode of storage and use it as blanket material for breeder reactor production of electricity.	•	
15	Mr. Steven Pattinson A.B. Machine Company, Ltd. Canada	See Document No. 36	See Document No. 36	

Doc. No.	Respondent	Summary of Recommendation(s)	Feasible	Not Feasible
16	Dana Lee Fluor Daniel, Inc. Irvine, California	Two options for the recovery of anhydrous hydrogen fluoride (AHF) from the conversion of depleted UF_6: (1) two-part process for the dry conversion of depleted UF_6 to UO_2 with the dehydration of off-gases to produce AHF; (2) two-part process for the classical conversion of depleted UF_6 to uranium metal using magnesium, with the intermediate conversion to UF_4 and the resultant production of AHF recovered from magnesium fluoride (MgF_2).	•	
17	Ms. Vina Colley c/o Portsmouth/Piketon Residents for Environmental Safety and Security McDermott, Ohio	Modify and improve storage facilities and procedures. If armament is going to be manufactured, then waste generation should be mitigated and health risks assessed. Raises questions about the viability of using depleted UF_6 as canister liners for radioactive waste disposal due to concern about toxicity of decaying uranium.	•	
18	Mr. Steven T. Carter Ohio Valley Regional Development Commission Portsmouth, Ohio	(Option 18-1) refeeding the stored depleted uranium cylinders back into the gaseous diffusion plant cascades; (Option 18-2) using the AVLIS process, which may decrease the amount of ^{235}U remaining in the depleted UF_6; and (Option 18-3) relates to stabilization of local employment; that is, to limit construction of any new manufacturing process designed to convert or use the depleted UF_6 to the affected plant site to stabilize regional employment.	18-2 • (no consensus -- concerns about time and cost of implementing AVLIS)	18-1 • (would not significantly reduce inventory; potentially cost prohibitive)
19	Mr. Jeffrey R. Williams Department of Energy Washington, D.C.	Use depleted uranium metal in support of both the Multi-Purpose Canister (MPC) subsystem and the General Atomics truck cask subsystem.	• (with qualifier -- may not make significant reduction in inventory)	
20	Mr. Tom Roberts Rental Enterprise Paducah, Kentucky	Proprietary	Proprietary	
21	Mr. Carl Cooley Department of Energy Germantown, Maryland	Summary of ongoing activities within the DOE.	Contained no recommendations	
22	Mr. Charles R. Schmitt Oak Ridge, Tennessee	Recommends conversion to uranium trioxide (UO_3).	• (with qualifier -- conversion to UO_3 is possible to pursue as R&D)	

Doc. No.	Respondent	Summary of Recommendation(s)	Feasible	Not Feasible
23	Mr. Robert Bernero, Director United States Nuclear Regulatory Commission Washington, D.C. (POC, Michael Weber)	Convert to triuranium octaoxide (U_3O_8) and place material in a mined cavity	•	
24	Mr. Dennis Lehan Nuclear Metals, Inc. Concord, Massachusetts	(Option 24-1) utilize the UF_6 in metal or oxide form in a variety of product applications; (Option 24-2) convert the UF_6 to metal using the Ames process and develop a leaching process to first decontaminate the magnesium fluoride (MgF_2) and then use it with sulfuric acid (H_2SO_4) as feedstock to produce AHF; and (Option 24-3) develop a new process for high temperature continuous reduction (HTCR) of the UF_4 to produce uranium metal.	24-1 • 24-2/3 •	
25	Mr. Charles Montford GenCorp Aerojet Jonesborough, Tennessee	Reduce to depleted uranium tetrafluoride (UF_4) and then to metal for further processing into products and/or for long-term storage or disposal. Uranium metal is currently being used as starting material for the AVLIS process, and when the metal is vaporized in the process, uranium enriched in ^{235}U is separated and solidified as depleted uranium alloy. It is stated that the tails can be reduced to metal, prepared as starting material for the AVLIS process, and used to produce an enriched product at a lower cost for enrichment than the current gaseous diffusion process.	•	
26	Corrine Whitehead Coalition for Health Concern Benton, Kentucky	On-site aboveground storage of the radioactive wastes in earthquake-proof concrete structures to allow for monitoring of surface leaks and radiation releases. Recommends residents living near the site be relocated and compensated for damages done to their property by DOE.	• (with qualifier that earthquake proof storage is not warranted)	
27	Mr. N. Dean Eckhoff Kansas State University Manhattan, Kansas	Convert to a more stable chemical form, such as an oxide, and stored for future use as an energy source. Convert ^{238}U to ^{239}Pu for use as reactor fuel to produce electricity	• (with qualifier -- implementation of breeder reactors is tentative and, if employed, likely to occur beyond 2020)	
28	Ms. Mildred Serra Knoxville, Tennessee	No recommendations for technologies or uses	Contained no recommendations	

Doc. No.	Respondent	Summary of Recommendation(s)	Feasible	Not Feasible
29	Mr. Harry A. Nesteruk M4 Environmental L.P. Oak Ridge, Tennessee	Apply M4 patented Catalytic Extraction Process to the conversion of UF_6 to either uranium oxide or metal.	•	
30	Dr. John D. Hewes Allied Signal, Inc. Morristown, New Jersey	This response recommends the conversion of depleted UF_6 to U_3O_8 for disposal or reuse, with the concurrent production of commercially valuable hydrofluorocarbons (HFCs) and anhydrous hydrogen fluoride (AHF).	•	
31	Mr. Thomas McWilliams Department of the Army Picatinny Arsenal, New Jersey (POC, George O'Brien)	Produce drill collars, well penetrators, and well shape charge perforators for use in the U. S. oil well drilling industry.	•	
32	Dr. Velma Shearer Englewood, Ohio	Against maintaining current storage and management practices based on health and safety concerns and against use as shielding or in armaments. Convert to an unspecified solution that would produce fluorides, which could be sold for other industrial uses, or to metal to be mixed with concrete slurry or sand and returned for deposit in abandoned uranium mines.		• (stated concerns about storage are not supported; oxide is a more likely and acceptable disposal form than metal; uranium mines pose environmental risks as disposal sites)
33	Mr. Ronald Lamb Lamb Wheel Alignment Kevil, Kentucky	Storage in aboveground, earthquake-proof, non-corrosive concrete storage structures that are off the ground so that monitoring for surface leaks and radiation release can be performed. Stabilize and clean the affected site area and adjacent lands to the extent required by law and offer relocation or compensation to landowners for damages to their land and homes.	• (with qualifier that earthquake proof storage is not warranted)	
34	Ms. Diana Salisbury Serpent Mound/Ohio Brush Creek Alliance Sardinia, Ohio	No recommendation for technologies or uses.	Contained no recommendations	

Doc. No.	Respondent	Summary of Recommendation(s)	Feasible	Not Feasible
35	Mr. Peter L. Lenny Cameco Corporation Canada	Use of a defluorination process to recover anhydrous hydrogen fluoride (AHF) and depleted uranium oxide, preferably depleted triuranium octaoxide (U_3O_8) in powder form, for storage or use in the production of various products. (Option 35-1) use of a multistage pyrohydrolysis process with steam and hydrogen or ammonia to produce triuranium octaoxide (U_3O_8) and uranium dioxide (UO_2); (Option 35-2) use of respondent's process that uses sulfuric acid (H_2SO_4) to convert UF_6 into a uranyl sulfate complex, which is subsequently subjected to a thermal decomposition process producing U_3O_8 and an off-gas; and (Option 35-3) use of a uranium metal/magnesium sulfate process to recover uranium metal, with further conversion of the resulting magnesium fluoride to AHF and crystallized magnesium sulfate.	35-1 • 35-2 • 35-3 •	
36	Mr. Stephen Pattinson A.B. Machine Company Ltd. Canada M1S 3R3	Proprietary	Proprietary	
37	Dr. Charles Forsberg Oak Ridge National Laboratory Oak Ridge, Tennessee	Convert into small borosilicate glass beads for use as a backfill material inside repository waste packages containing light water reactor (LWR) spent nuclear fuel (SNF).		• (substantial research and development required; lack of sufficient information - e.g., potential waste streams)
38	Mr. Earl Leming State of Tennessee Oak Ridge, Tennessee	Responds to the Advance Notice of Intent rather than to the Request for Recommendations. A recommendation is included to gradually convert the depleted UF_6 to an oxide over a 15- to 20-year period.	•	
39	Ms. Sue Whayne Clinton, Kentucky	Radioactive materials be stored in a seismically safe manner, and relocate and compensate residents who have already been affected. Onsite, aboveground concrete storage be "earthquake proof" and the cylinders be stacked high enough off the ground to be monitored for leaks.	• (with qualifier that earthquake proof storage is not warranted)	

Doc. No.	Respondent	Summary of Recommendation(s)	Feasible	Not Feasible
40	Mr. Victor Ransom Purdue University West Lafayette, Indiana	^{238}U in the depleted uranium be maintained so that it is available for potential use in the production of plutonium fuel in breeder reactors.	• (with qualifier -- implementation of breeder reactors is tentative and, if employed, likely to occur beyond 2020)	
41	Mr. Stephen Schutt Advanced Recovery Systems Erwin, Tennessee	Utilize two potential technologies to decontaminate the magnesium fluoride (MgF_2)low level radioactive waste (LLRW) resulting from the conversion of depleted UF_6 to uranium metal: (1) a patented hydrometallurgical process (DeCaF™) has been bench proven and is moving to the pilot plant testing stage and (2) a thermal recovery process (TherMag™) is under development.	•	
42	Mr. Jerry Hutchison R&R International, Inc. Akron, Ohio	Creation of a Kentucky Wastes and Energy Interim Storage and Transportation Facility (KY WEST) to centralize the depleted uranium stockpile for interim storage.		• (increased risks from transportation, without foreseeable permanent use or disposal)
43	Dana Lee Fluor Daniel Irvine, California	Non-proprietary summary submitted for Document No. 16, which was designated proprietary	See Document No. 16	
44	Mr. William Tewes Oak Ridge, Tennessee	No recommendations for technologies or uses.	Contains no recommendations	
45	Mr. Peter MacDowell St. Helen's Trading, Ltd. Azusa, California	Interested in the depleted uranium stockpile if it can be converted into a solid form in order to recycle Naturally Occurring Radioactive Material (NORM) into shielding bricks to serve as a bulk shielding medium for contaminated facilities at Chernobyl.	•	
46	Mr. Archer Haskins Nuclear Fuels Services, Inc. Lynchburg, Virginia	This document was a statement of capabilities.	Contains no recommendations	
47 (P9)	Mr. Steven Baker EG&G Environmental, Inc. Richland, Washington	Recommends a use for the fluorine in the UF_6 conversion process by reacting the UF_6 gas with alumina (Al_2O_3) or aluminum metal. The process would produce aluminum trifluoride (AlF_3), a primary material used by the aluminum industry in electric cells (or "pots") that reduce alumina to aluminum metal.	•	

Doc. No.	Respondent	Summary of Recommendation(s)	Feasible	Not Feasible
48 (P10)	Mr. Charles Chisholm PDI Reno, Nevada	A mined geologic formation be considered for the long-term management of the depleted uranium or products resulting from the processing of the depleted uranium.	•	
49	Package 5 Continuous Metallothermic Reduction to Uranium Metal *(DOE Option Under Consideration)*	Replace the batch reduction process with a continuous metallothermic reduction process to reduce depleted UF_6 first to uranium tetrafluoride, then reduce the uranium tetrafluoride to uranium metal to provide a uranium/iron metal alloy for the Uranium-AVLIS process.	• (with qualifier -- additional work required on metallothermic reduction technology)	
50	Package 6, 7, 8 Conversion to Ceramic UO_2 Existing Industrial Routes *(DOE Option Under Consideration)*	Conversion of depleted UF_6 using the same process used for converting isotopically enriched UF_6 to ceramic uranium dioxide, using either a wet or dry process.	•	
51	Package 9 Conversion to Ceramic UO_2 Gelation *(DOE Option Under Consideration)*	Convert into ceramic uranium dioxide based upon gelation methods.	• (warrants further development)	
52	Package 10 Conversion to Uranium Carbide - Graphite and Gelation Approaches *(DOE Option Under Consideration)*	Convert to dense uranium carbide using either a graphite or gelation process for potential use as a reactor fuel for certain high temperature reactors.	•	
53	Package F1 HTGR Fuel Fabrication Using Uranium Carbide *(DOE Option Under Consideration)*	Convert to uranium dioxide, with further conversion into uranium carbide for use as high-temperature gas-cooled reactor (HTGR) fuel.		• (lack of demand for HTGR fuel; little or no reduction of UF_6 inventory)

Doc. No.	Respondent	Summary of Recommendation(s)	Feasible	Not Feasible
54	Mr. Yoshihiko Sugano Mitsubishi Materials Corporation Energy and Ecosystem Business Japan	Proprietary	Proprietary	
55	Mr. Charles Montford GenCorp Aerojet Jonesborough, Tennessee	Complementary information to the original response. Recommends the conversion of depleted UF_6 to the tetrafluoride, and batch metallothermic reduction of the tetrafluoride to the metal using magnesium.	•	
56	Mr. William H. Carder Scientific Ecology Group, Inc. Oak Ridge, Tennessee	A notification of intent to submit an unsolicited proposal.	Notification of Intent to Submit An Unsolicited Proposal	
57	Mr. Mike H. West Mr. John FitzPatrick Los Alamos National Laboratory Los Alamos, New Mexico	Use as a fluorinating agent to produce fluorocarbons rather than production of anhydrous hydrogen fluoride (AHF). The respondent proposes management of depleted UF_6 to allow maximum flexibility for future uranium processing [e.g., conversion to uranium tetrafluoride (UF_4) for further conversion to uranium metal, uranium dioxide (UO_2), uranium trioxide (UO_3), or triuranium octaoxide (U_3O_8)].	• (with qualifier -- more information is needed)	

GROUPING OF RESPONSES INTO TECHNOLOGY OPTIONS

Responses to the Request for Recommendations that were determined to be feasible have been grouped into four categories of options: conversion, storage, recycle/reuse, and disposal. **Conversion** encompasses chemical processes for converting UF_6 into other forms. Conversion to the oxide forms—triuranium octaoxide (U_3O_8), uranium dioxide (UO_2), and uranium trioxide (UO_3)—and also to uranium metal and uranium carbide (UC, UC_2) was recommended. Conversion of the depleted UF_6 to another form such as an oxide or metal would be necessary to implement most other options (e.g., recycle/reuse, disposal). **Storage** options are defined by the type of facilities and the chemical form of the uranium to be stored. The generic types of storage facilities include outside yards, buildings, and vaults. Forms of uranium for storage include UF_6, U_3O_8, UO_2 (ceramic), and U_{metal}. Various **recycle/reuse** options were recommended, including dense material applications, re-enrichment (via Atomic Vapor Laser Isotope Separation [AVLIS], centrifuge, or refeed/blending), shielding (uranium metal and DUCRETE), and Advanced Fuel Reactor Fuel Cycle. **Disposal** options were defined by the uranium chemical form, the waste form, and characteristics of the disposal site. Disposal forms could include oxides (e.g., U_3O_8, UO_2) and metal. These categories of options will facilitate further evaluation of the options in the Engineering Analysis and other portions of the Depleted Uranium Hexafluoride Management Program.

Table 4 shows the four categories of options and the feasible recommendations, by document number, related to each. Responses listed more than once contained more than one recommended technology or use.

Several of the responses to the Request for Recommendations were considered by the reviewers to be feasible, with qualifiers. These generally included recommendations that appeared to require further development, would not be implemented by 2020, or would not likely consume a significant portion of the depleted UF_6 inventory. Qualifiers are briefly stated in Table 3.

Also as indicated in Table 3, six recommendations were concluded by the reviewers to be infeasible. These recommendations were

- use of a Titan missile or space shuttle to send the depleted UF_6 to the sun;
- refeed of the stored depleted UF_6 back into the gaseous diffusion plant cascades;
- ceasing current storage practices, based on health and safety concerns, and pursuing conversion to an unspecified solution producing salable fluorides, or to metal which would be mixed with slurry or sand and deposited in abandoned uranium mines;
- conversion to small borosilicate glass beads for use as a backfill material inside repository waste packages;
- shipment to a centralized facility in Kentucky for interim storage;

- conversion to uranium dioxide, with further conversion to uranium carbide for use as high-temperature gas-cooled reactor fuel.

Table 4
Depleted Uranium Hexafluoride Management Program
Technology Assessment Report - Option Categories

OPTION CATEGORY		RECOMMENDATION (Per Document No.)
CONVERSION	a. UF_6 ---> oxide	
	1. U_30_8	4-1, 6, 9, 10, 13-1, 23, 30, 35-1, 35-2, 38, 47
	2. UO_2	6, 27, 35-1, 50, 51, 57
	3. UO_3	22
	b. UF_6 ---> U_{metal}	2-4, 4-2, 5-3, 12, 16, 24-2, 24-3, 25, 29, 35-3, 41, 49, 55
	c. UF_6 ---> UC, UC_2	52
STORAGE	a. UF_6 storage	14, 17, 26, 33, 38, 39, 48
	b. Oxide	13-2, 25, 27, 48, 55
	c. Metal	25, 48, 55
RECYCLE/ REUSE	a. Dense Material Applications	5-2, 25, 31, 55
	b. Re-enrichment	2-1, 2-2, 5-3, 13-3, 18-2, 24-1, 25, 55
	c. Shielding	2-3, 5-1, 19, 45
	d. Advanced fuel cycle	1, 11, 13-3, 14, 27, 40
DISPOSAL	a. Oxide	5-4, 23, 25, 48, 55
	b. Metal	48, 25, 32, 48, 55

CONCLUSION

Many of the options recommended in response to the Request for Recommendations were already known, while other recommendations contained information on unique technologies and potential uses that had not been previously evaluated. The goal in issuing the Request, to help ensure that Department management considers a wide variety of reasonable options for the long-range management strategy, was therefore achieved. The *Technology Assessment Report* provides a sound basis for the further evaluation of these options.

FOR FURTHER INFORMATION

To receive further information or to be placed on the mailing list, please contact Mr. Charles E. Bradley, Jr., DOE Program Manager (301/903-5512).