ATTACHMENT 1

Louisiana Energy Services
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Lawrence Livermore National Laboratory
"Cost Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride"
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COST ANALYSIS REPORT FOR THE LONG-TERM MANAGEMENT OF DEPLETED URANIUM HEXAFLUORIDE

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May 1997

Lawrence Livermore National Laboratory

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1. INTRODUCTION

With the publication of a Request for Recommendations and Advance Notice of Intent in the November 10, 1994, *Federal Register* (59 FR 56324 and 56325), the Department of Energy (DOE) initiated a program to assess alternative strategies for the long-term management or use of depleted uranium hexafluoride (UF_6) stored in the cylinder yards at Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. The current management strategy entails handling, inspection, monitoring, and maintenance activities to ensure safe storage of the depleted UF_6. Six long-term management strategy alternatives are being analyzed in a draft Programmatic Environmental Impact Statement (PEIS) (DOE, forthcoming 1997). These alternatives include the current management strategy (the "No Action alternative"), two long-term storage alternatives, two use alternatives, and a disposal alternative. Complete management strategies may also involve transportation and, in many cases, conversion to another chemical form.

This *Cost Analysis Report* was developed to provide comparative cost data for the management strategy alternatives being examined. The draft PEIS and the *Cost Analysis Report* will be used by DOE in the decision-making process, which is expected to result in a Record of Decision in 1998, completing the first phase of the Depleted UF_6 Management Program, management strategy selection. During the second phase of the Program, site-specific and technology-specific issues will be addressed.

This report presents life-cycle cost estimates for each of the management strategy alternatives. The cost analysis estimates the primary capital and operating costs for the different alternatives and reflects all development, construction, operating, and decontamination and decommissioning (D&D) costs, as well as potential off-setting revenues from the sale of recycled materials. The costs are estimated at a scoping or preconceptual design level and are intended to assist decision makers in comparing alternatives. The focus is on identifying the relative differences in the costs of alternatives for purposes of comparison, not on developing absolute costs for project budgets or bid-document costs. The technical data upon which this cost analysis is based is principally found in the *Engineering Analysis Report* (Dubrin et al. 1997).

Section 2 of this report introduces the options and alternative strategies included in the draft PEIS. Section 3 presents the basis for the cost estimates for each of the options considered. Section 4 presents the cost estimates for the options. Section 5 presents the cost estimates for the alternative management strategies, which were developed by linking together the cost estimates for individual options. Section 6 discusses the uncertainty in the cost estimates for the alternative strategies and provides an analysis of the sensitivity of the cost estimates to a variety of assumptions.

2. OPTIONS AND ALTERNATIVE MANAGEMENT STRATEGIES

Six long-term management strategy alternatives are being analyzed in the PEIS, including the current management strategy (the "No Action alternative"), two long-term storage alternatives, two use alternatives, and a disposal alternative. The disposal alternative leads to final disposition, while the other alternatives have varying endpoints. A management strategy may include various activities such as transportation, conversion, use, storage and/or disposal. The process of constructing each of these management strategy alternatives entailed the systematic combination of selected *options* for the various activities, which formed the logical building blocks for the alternatives, as well as the basis for the organization of this document.

To analyze the costs of a given alternative, the costs of each option for activities composing that alternative were evaluated. In cases where different options were available to implement a particular alternative, the analysis considered several options. After all costs for the options composing a particular alternative were defined, the costs were summed to yield a total cost for the alternative.

2.1 Categories of Options

The following option categories are considered in this report:

- Continued cylinder storage at current sites
- Transportation
- Conversion
- Storage
- Manufacture and use
- Disposal

An option category designates a major activity in a management strategy which can be accomplished in various different ways. Each of the following discussions includes a brief examination of the options within that category, along with descriptions of specific activities or requirements associated with each option and reasons for its consideration in particular contexts. With the exception of continued cylinder storage at current sites, the technical data are found in the *Engineering Analysis Report* (Dubrin et al. 1997). Continued storage activities are described in other programmatic documents, identified in Section 2.1.1.

Facilities for the conversion, manufacture, storage, disposal, or transfer of depleted UF_6 are assumed to be constructed and operated at a generic green field site. For purposes of analysis, a period of 20 years from the onset of operations is assumed to disposition the entire depleted uranium stockpile (about 560,000 metric tons [MT] of UF_6 in 46,422 cylinders). This corresponds to an annual throughput rate of 28,000 MT of UF_6 or about 19,000 MT of depleted uranium.

2.1.1 Continued Cylinder Storage at Current Sites

Continued cylinder storage refers to the activities associated with the present approach to storing depleted UF_6 at the K-25 site at Oak Ridge, the Paducah site, and the Portsmouth site. Storage of depleted UF_6 is included under all alternative management strategies considered, the main difference being the *duration* of the storage period. In the "No Action" alternative, all of the cylinders remain in storage indefinitely. In the "action" alternatives, the cylinder inventory declines at five percent (5%) per year beginning in 2009.

The surveillance and maintenance activities that would be undertaken from now until September 30, 2002, are described in detail in the *UF_6 Cylinder Program Management Plan* (CPMP) that was submitted to the Defense Nuclear Facilities Safety Board in July 1996 (LMES 1996). Surveillance and maintenance activities are expected to continue beyond fiscal year 2002, but the scope of the CPMP was limited. Assumptions were developed to estimate the impacts and cost of continued storage because the assessment period for the draft PEIS and cost analysis extends to 2040. In developing these assumptions, it was recognized that the details of the activities actually undertaken in the future may differ from those described in the CPMP due to unexpected field conditions or budgetary constraints. A memo by Joe W. Parks, Assistant Manager for Enrichment Facilities, DOE Oak Ridge Operations Office (Parks 1997), documents assumptions for evaluating continued cylinder management activities for the No Action alternative.

The Parks memo was used as follows to develop the cost estimates for the alternatives considered in this report:

<u>No Action Alternative</u>

1999-2039	Continued cylinder storage activities as described in Parks memo

<u>Action Alternatives</u>

1999-2008	Continued cylinder storage activities as described in Parks memo
2009-2029	Continued storage of cylinders awaiting conversion or storage at another location (inventory declining 5% per year). Annual inspections (visual and ultrasonic) and valve monitoring/maintenance activities and cylinder breaches, as described in the Parks memo, decline proportionally to the reducing inventory. Repainting of the inventory would occur every ten years until 2019, when cylinders would be removed within the 10-year paint life.

The activities supporting continued cylinder storage analyzed in this document include the following:

- Routine visual and ultrasonic inspections of cylinders
- Cylinder painting
- Cylinder valve monitoring and maintenance
- General storage yard and equipment maintenance
- Yard reconstruction to improve storage conditions

- New storage yard construction
- Relocation of cylinders to new yards or to improve access for inspections
- Repair (patch welding) and contents transfer for breached cylinders
- Data tracking, systems planning and execution, and conduct of operations

The total inventory of 46,422 depleted UF_6 cylinders is currently stored as follows: 28,351 cylinders (about 60%) are stored in 13 yards at the Paducah site, 13,388 cylinders (about 30%) are stored in two yards at the Portsmouth site, and 4,683 cylinders (about 10%) are stored in three yards at the K-25 site. An intensive effort is ongoing to improve yard storage conditions. This effort includes (1) relocation of cylinders which are too close to one another to allow for adequate inspections and (2) construction of new storage yards or reconstruction of existing storage yards to provide a stabilized concrete base and monitored drainage for the cylinder storage areas. The costs for reconstruction of four Paducah yards, construction of a new yard at the K-25 site, and relocation of about 19,000 cylinders at Paducah and all the cylinders at K-25 are included in this report.

Most cylinders are inspected every four years for evidence of damage or accelerated corrosion. Annual inspections are required for cylinders that have been stored previously in substandard conditions and/or show areas of heavy pitting or corrosion (about 25 percent of the cylinder population). In addition to these routine inspections, ultrasonic testing inspections are currently conducted on some of the relocated cylinders. The ultrasonic testing is a nondestructive method to measure the wall thickness of cylinders. Valve monitoring and maintenance are also conducted for cylinders that exhibit discoloration of the valve or surrounding area during routine inspections. Leaking valves are replaced in the field.

For the No Action alternative, the frequency of routine inspections and valve monitoring is assumed to remain constant through 2039. Ultrasonic testing is assumed to be conducted annually for 10% of relocated cylinders; after relocation activities are finished, around the year 2003, 10% of the cylinders painted each year are assumed to receive ultrasonic testing inspections. For the action alternatives, the frequency of inspections is assumed to decrease with decreasing cylinder inventory from 2009 to 2029.

Cylinder painting will be employed at the three sites to reduce cylinder corrosion. The paint currently planned for use is assumed to have a lifetime of 10 years. Although repainting may not actually be required every 10 years, or budgetary constraints may preclude painting every 10 years, the continued cylinder storage analysis under the No Action alternative assumes a 10-year cycle for painting. Activities associated with breached cylinders are also assessed.

2.1.2 Transportation

Transportation involves the movement of materials among the facilities that play a role in the various alternative management strategies. With the exception of the No Action alternative, transportation occurs under each alternative, in some cases representing two or three separate steps in the process of managing depleted UF_6. Two modes — truck and rail —are considered. The following elements are included in transportation:

- Preparation of depleted UF_6 cylinders for shipment

- Transport of all forms of depleted uranium (i.e., UF_6 from the current storage sites; U_3O_8, UO_2, and U metal from conversion facilities; and uranium shields from manufacturing facilities)

- Cylinder treatment (i.e., cleaning the emptied cylinders to remove the depleted UF_6 heel, crushing the cleaned cylinders, and transporting the crushed cylinders to a DOE scrap yard)

Preparation for shipment cost refers to the cost associated with the activities required to prepare depleted UF_6 cylinders for transportation from the three current storage sites. Cylinder preparation would be required for alternatives that involve transport of cylinders to a conversion facility or a long-term storage site. The draft PEIS assumes that all alternatives except "No Action" may require transport — that is, neither long-term storage nor conversion would occur at the current storage sites. Actual siting of facilities will be considered during Phase II of the depleted UF_6 Management Program. Preparation of cylinders for shipment would occur at each of the sites currently storing depleted UF_6.

Although the cylinders currently used for storing depleted UF_6 were designed and built to meet U.S. Department of Transportation (DOT) requirements for shipment, some of the cylinders no longer meet those requirements. Review of Title 49 of the Code of Federal Regulations (CFR), the American National Standards Institute's ANSI N14.1, and the U.S. Enrichment Corporation's USEC-651, along with other documents, has helped identify three categories of cylinder problems: overpressured, overfilled, and substandard. Overpressured cylinders do not meet the requirement that they be shipped at subatmospheric pressures. Overfilled cylinders contain an inventory of UF_6 which exceeds allowable fill limits for shipping. Substandard cylinders do not meet the "strong, tight" requirements for shipment; substandard cylinders include those having corrosion sufficient for the wall thickness to be below allowable minimums, damaged cylinders, and cylinders with plug or valve threading problems or other nonconformances that prevent shipment "as-is."

Cylinders that meet DOT shipment requirements would require no special preparation and could be shipped whenever desired. Depleted UF_6 in cylinders that no longer meet DOT requirements would be prepared for shipment in one of two ways:

- The placement of the nonconforming cylinder in a *cylinder overcontainer* — a protective metal container slightly larger than the cylinder itself and designed to meet all DOT shipment requirements; or

- The transfer of depleted UF_6 from cylinders that no longer meet DOT requirements to new cylinders which do meet these requirements, with the transfer to occur at the storage site in a new facility designed specifically for this activity.

The second element of the transportation category of options, transport, includes costs for loading, shipping, and unloading activities. Loading/unloading and trip costs ($/kilometer [km]) were considered to be dependent upon mode (i.e., truck or rail), material packaging, and density. These dependencies were the same, regardless of the chemical form of the cargo. For example, transport of UF_6 was assumed to cost the same per railcar per kilometer as transport of U_3O_8, the only difference being the amount of material in a load.

The final element of the transportation category of options is treatment and transport of emptied cylinders. Most of the alternatives being considered involve removing the depleted

UF_6 from the cylinders and converting it to another form. After the cylinders are emptied, they would be washed to remove the residual heel of depleted UF_6. It is assumed that the cleaned cylinders would be crushed and then transported to the gaseous diffusion plant sites, where they would become part of the scrap metal inventory. Disposition of the emptied cylinders (46,422) and the residual "heel" of depleted UF_6 is addressed under cylinder treatment (see Section 4.1.2).

2.1.3 Conversion

Conversion of the depleted UF_6 to another chemical form is required for most management strategy alternatives. The following conversion options are considered:

- Conversion to triuranium octaoxide (U_3O_8)
- Conversion to uranium dioxide (UO_2)
- Conversion to metallic uranium

Due to their high chemical stability and low solubility, uranium oxides in general are presently the favored forms for the storage and disposal alternatives. High density UO_2 and uranium metal are the preferred forms for spent nuclear fuel radiation shielding applications due to their efficacy in gamma ray attenuation. It is assumed that the entire inventory of depleted UF_6 could be converted over a 20-year period at a single industrial plant built for and dedicated to this task. Two different processes for the conversion to U_3O_8, three different processes for the conversion to UO_2, and two different processes for the conversion to metal are considered.

The Engineering Analysis Project developed two suboptions for the dry conversion of UF_6 to U_3O_8. The first process upgrades the concentrated hydrogen fluoride (HF) by-product to anhydrous HF (AHF < 1% H_2O). In the second process, the acid would be neutralized with lime to produce calcium fluoride (CaF_2).

The conversion of UF_6 to dense UO_2 is industrially practiced in the nuclear fuel fabrication industry. By either a "wet" or a "dry" process, the UF_6 is converted to a low-density UO_2 powder under controlled conditions to assure suitable powder morphology for sintering to high density for use as power reactor fuel pellets. Three suboptions were developed in the Engineering Analysis Project for the conversion of UF_6 to UO_2. A generic industrial dry process with conversion (similar to that used for U_3O_8) followed by conventional pelletizing and sintering to produce centimeter-sized pellets is the basis for the first two suboptions. The first suboption upgrades the concentrated HF to AHF (< 1% H_2O). The second suboption neutralizes the HF to CaF_2 for sale. The third suboption, a wet process, is based on small scale studies and is referred to as the gelation process.

As described above, it is assumed that the AHF and CaF_2 conversion products are of sufficient purity to be sold for unrestricted usage. Vulnerabilities associated with this assumption are addressed in Section 6.3.1.

Two metallothermic reduction routes (batch and continuous) for the production of uranium metal were analyzed. Both processes have the same chemistry: the magnesium metal (Mg) reduction of uranium tetrafluoride (UF_4) to produce uranium metal and a magnesium fluoride (MgF_2) by-product slag. The UF_4 required for either process would be generated by the hydrogen (H_2) reduction of depleted UF_6 (a standard industrial process), producing AHF as the by-product. The standard industrial process for over 50 years has been the

batch metallothermic reduction process. The MgF_2 by-product slag resulting from this process is contaminated with appreciable quantities of uranium. Without further treatment, the slag must be disposed of as a low-level waste (LLW). With the rising cost for LLW disposal, disposal has become a significant fraction of the total cost for producing uranium metal. For the batch metallothermic suboption, an acid leaching step to reduce the uranium content in the slag and potentially enable it to be disposed in a sanitary landfill is analyzed. An exemption would be required since the uranium activity in the treated slag would still be large compared to that in typical soils.

The other suboption analyzed in depth is the continuous metallothermic reduction process, which is currently under development. The initial expectation is that the level of uranium contamination in the MgF_2 by-product would be sufficiently low that a post-treatment step such as the acid leaching step used in the batch metallothermic process would not be necessary. Nevertheless, an exemption for disposal in a sanitary landfill would be required because of the small amount of remaining uranium. Process vulnerabilities associated with metal conversion options are further discussed in Section 6.3.2.

2.1.4 Long-Term Storage

Two alternatives analyzed involve long-term storage. Emplacement in the storage facility would occur over 20 years at a newly constructed consolidated facility and the facility would be monitored thereafter. In the engineering analysis, storage options are defined by the type of storage facility, and suboptions are defined by the chemical form in which the depleted uranium is stored. The types of storage facilities analyzed in the *Engineering Analysis Report* and the draft PEIS are (1) buildings, (2) below ground vaults, and (3) mined cavities. The three chemical forms analyzed are (1) UF_6, (2) U_3O_8, and (3) UO_2. The two long-term storage alternatives considered in the draft PEIS are storage of the depleted uranium as UF_6 and storage in an oxide form (either U_3O_8 or UO_2).

In the case of storage as U_3O_8, following conversion, the U_3O_8 would be stored in powdered form in 55-gal (208-liter [L]) drums. The drums would be placed in buildings, below ground vaults, or an underground mine for monitored storage. Compared to depleted UF_6, U_3O_8 provides greater chemical stability, although storage in the converted form may be less flexible, and therefore more costly, for potential future uses. In the case of storage as UO_2, following conversion, the UO_2 would be stored as dense microspheres (the product of the gelation process) or pellets in 30-gal (110-L) drums, with the drums placed in buildings, below ground vaults, or an underground mine. As with U_3O_8, the UO_2 form provides greater chemical stability compared to UF_6.

Long-term storage as UF_6 in the existing cylinders in either buildings or a mined cavity is also considered. Storage of UF_6 in the existing outdoor yards is addressed in Section 2.1.1.

2.1.5 Manufacture and Use

Currently, there exist several potential uses for depleted UF_6. The manufacture and use options evaluated in the *Engineering Analysis Report* and the draft PEIS focus on the use of depleted uranium to shield radiation. Due to its high density, depleted uranium, although radioactive itself, can be used to absorb the radiation from other, more highly radioactive materials. This shielding characteristic could be employed in the manufacture of casks for the spent nuclear fuel removed from DOE facilities or commercial nuclear power

plants. Two alternatives involving the manufacture and use of depleted uranium for shielding are considered: uranium dioxide (DUCRETE™)[1] and uranium metal.

DUCRETE™ is similar to concrete but contains high-density UO_2 in place of conventional aggregate (typically gravel) as a tempering agent mixed with cement for shielding in spent nuclear fuel (SNF) storage containers. Due to the high density of UO_2, achieving a particular level of radiation shielding using DUCRETE™ requires less than half the thickness of concrete. Such a dramatic reduction in shielding thickness provides both weight and size advantages over casks using concrete shielding. DUCRETE™ may also be an appropriate material for overcontainers for spent nuclear fuel disposal, although this application is more speculative than the storage applications because the precise disposal requirements are not known at this time. Accordingly, the engineering analysis assumes that, after the spent nuclear fuel storage period, the empty DUCRETE™ cask would be disposed as low-level waste when the spent fuel is disposed. The cost of disposal of the DUCRETE™ casks is not included. The timing of such activities is not known but is assumed to be beyond 2040.

The second use alternative involves using depleted uranium as the metal in the manufacture of annular shields for a multipurpose unit system. The multipurpose unit concept is a spent nuclear fuel package that, once loaded at the reactor, provides confinement of spent nuclear fuel assemblies during storage, transportation, and disposal. In this approach, the depleted uranium is disposed of with the spent nuclear fuel.

For purposes of analysis, it is assumed that (1) casks would be based on existing designs, with the uranium shielding material enclosed between stainless steel (or equivalent) shells; and (2) the shielded casks would be produced over a period of 20 years at a central stand-alone industrial plant, transported to commercial reactors, and loaded with spent nuclear fuel.

2.1.6 Disposal

Disposal refers to the emplacement of a material in a manner which ensures isolation for the indefinite future. Disposal is considered permanent, with no intent to retrieve the material for future use. The disposal options considered in the *Engineering Analysis Report* and PEIS involve conversion of the UF_6 and disposal as an oxide — either U_3O_8 or UO_2. The U_3O_8 would be disposed of in 55-gal (208-L) drums, and the UO_2 would be disposed of in 30-gal (110-L) drums. Both bulk disposal (i.e., the U_3O_8 powder or UO_2 microspheres are placed directly into drums) and grouted disposal (i.e., the oxide forms are mixed with cement before being placed in drums) are analyzed, as well as three types of disposal facility: shallow earthen structures, below ground vaults, and an underground mine. Each disposal facility would be stand-alone and single-purpose, composed of a waste form facility and several disposal units, which would vary depending on the type of facility involved.

[1] DUCRETE is a trademark of Lockheed Martin Idaho Technologies Company and is licensed to Nuclear Metals, Inc., Concord, MA.

2.2 Definition of Alternative Management Strategies

Selected options from the six categories described in Section 2.1 can be combined to build the following long-term management strategies being considered:

- No Action alternative
- Long-term storage as UF_6 in buildings or a mined cavity
- Long-term storage as oxide in buildings, vaults, or a mined cavity
- Use as uranium dioxide in DUCRETE™ for shielding applications
- Use as uranium metal for shielding applications
- Disposal as oxide in shallow earthen structures, vaults, or mined cavity

The draft PEIS studies the potential environmental impacts of these management strategy alternatives for the 41-year period from 1999 through 2039, although the strategies could continue beyond that date. Accordingly, the *Cost Analysis Report* analyzes the same time period.

The process of combining options into a management strategy entails selecting those options that fulfill the function(s) necessary to carry out a particular alternative. It is noted that the alternatives have varying endpoints. Figure 2.1 shows the different options in alternative management strategies. (All figures are located at the end of Chapter 2.)

2.2.1 No Action

The *Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act* (40 CFR Parts 1500-1508) require that a "No Action" alternative be considered when preparing an EIS. Under the No Action alternative, DOE would continue to store its inventory of full depleted UF_6 cylinders at the three existing sites indefinitely. The activities involved in continued storage are described in Section 2.1.1 and shown in Figure 2.2. Consistent with the PEIS time frame, costs of current management activities were estimated from 1999 through 2039.

2.2.2 Long-Term Storage as UF_6

The long-term storage as UF_6 alternative involves storage of depleted UF_6 in its current chemical form until 2040. This alternative combines options from four categories, including a transportation step to move the material from its current location to a long-term storage location.

- *Continued storage* as depleted UF_6 in the current yards from 1999 to 2029, with the amount of depleted UF_6 in storage decreasing by 5% per year from 2009 to 2029 until it is gone;
- *Cylinder preparation* for shipment from 2009 to 2029;
- *Transportation* as UF_6 to a consolidated storage facility from 2009 to 2029;

- *Long-term storage* as depleted UF_6 in buildings or a mined cavity from 2009 to 2040, with the amount of depleted UF_6 in storage increasing by 5% per year until all the depleted uranium is stored at a consolidated storage facility by 2029.

Under this alternative, continued storage at the current sites would occur through 2008. In the ensuing 20-year period, from 2009 until 2029, cylinder preparation for shipment, transportation to the long-term storage site, and placement in the long-term storage facility would occur. As the amount of depleted UF_6 in current storage conditions declines over this two-decade period, the amount of depleted UF_6 in long-term storage increases. Once all of the cylinders have been shipped (2029), the long-term storage facility would enter a maintenance and monitoring mode until 2040. No decision has yet been made regarding what will happen to the stored UF_6 after 2040. Long-term storage as UF_6 is shown in Figure 2.3.

2.2.3 Long-Term Storage as Uranium Oxide

The long-term storage as uranium oxide alternative considers long-term storage of depleted uranium after it has been converted to either U_3O_8 or UO_2. It is assumed that both the conversion process and long-term storage would occur at locations other than the sites presently used for depleted UF_6 storage.

The combination of options making up the long-term storage as oxide alternative fall into seven different steps, two of which are transportation:

- *Continued storage* as depleted UF_6 in the current yards from 1999 to 2029, with the amount of depleted UF_6 in storage decreasing by 5% per year beginning in 2009 until it is gone in 2029;
- *Cylinder preparation* for shipment from 2009 to 2029;
- *Transportation* as UF_6 from 2009 to 2029;
- *Conversion* to oxide from 2009 to 2029;
- *Transportation* as oxide from 2009 to 2029;
- *Cylinder treatment* from 2009 to 2029;
- *Long-term storage* as oxide in a building, vault, or mined cavity from 2009 to 2040, with the amount of oxide in storage increasing by 5% per year until all the depleted uranium is stored in this form by 2029.

Once again, continued storage persists through 2029. Most of the activity under this alternative would occur in the period beginning in 2009 and continuing for 20 years: cylinders would be prepared for transportation and transported to a conversion facility; the depleted UF_6 would be converted to oxide; and the oxide would be moved to a long-term storage facility. The inverse, complementary relationship between current storage and long-term storage also persists, with the former declining as the latter increases with the transfer of material from the current sites to a long-term storage facility. Once all of the material has been shipped, the long-term storage facility would enter a maintenance and monitoring mode until 2040. Long-term storage as uranium oxide is shown in Figure 2.4.

2.2.4 Use as Uranium Dioxide in DUCRETE™ for Shielding Applications

One of the two use alternatives considered in the *Engineering Analysis Report* and the draft PEIS involves using depleted uranium to make a radiation shielding material known as DUCRETE™. Under this alternative, UF_6 would be converted to an oxide form (UO_2), which in turn would be used to manufacture DUCRETE™ casks for storing spent nuclear fuel.

This alternative consists of the following steps:

- *Continued storage* as depleted UF_6 in the current yards from 1999 to 2029, with the amount of depleted UF_6 in storage decreasing by 5% per year beginning in 2009 until it is gone in 2029;
- *Cylinder preparation* for shipment from 2009 to 2029;
- *Transportation* as UF_6 from 2009 to 2029;
- *Conversion* to UO_2 pellets from 2009 to 2029;
- *Transportation* as UO_2 from 2009 to 2029;
- *Cylinder treatment* from 2009 to 2029;
- *Manufacture* of DUCRETE™ casks from 2009 to 2029;
- *Transportation* as DUCRETE™ casks from 2009 to 2029;
- *Use* as DUCRETE™ casks beginning in 2009.

Storage as depleted UF_6 would continue to 2029. Beginning in 2009, cylinders would be prepared for transportation and transported to a conversion facility, where the depleted UF_6 would be converted to UO_2. The UO_2 would be transported to a facility that manufactures DUCRETE™ casks; the casks would be manufactured; and the finished casks would be transported to a commercial or DOE nuclear facility to be filled with spent fuel. Use would increase between 2009 and 2029 as continued storage decreases, with all of the depleted uranium in use in DUCRETE™ casks by 2029. Use as uranium dioxide in DUCRETE™ is shown in Figure 2.5.

2.2.5 Use as Uranium Metal for Shielding Applications

A second long-term management strategy for using depleted UF_6 is the use as metal alternative. Under this alternative, depleted UF_6 would be converted to metal, which in turn would be used to manufacture metal casks for spent nuclear fuel or high-level waste from commercial or DOE facilities.

The use as metal alternative consists of the following steps:

- *Continued storage* as depleted UF_6 in the current yards from 1999 to 2029, with the amount of depleted UF_6 in storage decreasing by 5% per year beginning in 2009 until it is gone in 2029;
- *Cylinder preparation* for shipment from 2009 to 2029;

- *Transportation* as UF_6 from 2009 to 2029;
- *Conversion* to metal from 2009 to 2029;
- *Transportation* as metal from 2009 to 2029;
- *Cylinder treatment* from 2009 to 2029;
- *Manufacture* of metal casks from 2009 to 2029;
- *Transportation* as metal casks from 2009 to 2029;
- *Use* as metal casks beginning in 2009.

Storage as depleted UF_6 would continue to 2029. Beginning in 2009, cylinders would be prepared for transportation and transported to a conversion facility, where the depleted UF_6 would be converted to metal. The metal would be transported to a facility that manufactures metal casks; the casks would be manufactured; and the finished casks would be transported to a commercial or DOE nuclear facility to be filled with spent fuel. Use would increase between 2009 and 2029 as continued storage decreases, with all of the depleted uranium in use in metal casks by 2029. Use as uranium metal is shown in Figure 2.6.

2.2.6 Disposal as Oxide

The disposal as oxide alternative considers the disposal of depleted uranium after it has been converted to U_3O_8 or UO_2. It is assumed that both the conversion process and the disposal would occur at different locations

The combination of options making up the disposal as oxide alternative fall into seven different steps, two of which are transportation:

- *Continued storage* as depleted UF_6 in the current yards from 1999 to 2029, with the amount of depleted UF_6 in storage decreasing by 5% per year beginning in 2009 until it is gone in 2029;
- *Cylinder preparation* for shipment from 2009 to 2029;
- *Transportation* as depleted UF_6 from 2009 to 2029;
- *Conversion* to U_3O_8 or UO_2 from 2009 to 2029;
- *Transportation* as U_3O_8 or UO_2 from 2009 to 2029;
- *Cylinder treatment* from 2009 to 2029;
- Disposal as oxide from 2009 to 2040, with the amount of oxide disposed increasing by 5% per year until all depleted uranium is disposed by 2029.

Disposal as oxide is shown in Figure 2.7

Figure 2.1 Options and Alternative Management Strategies

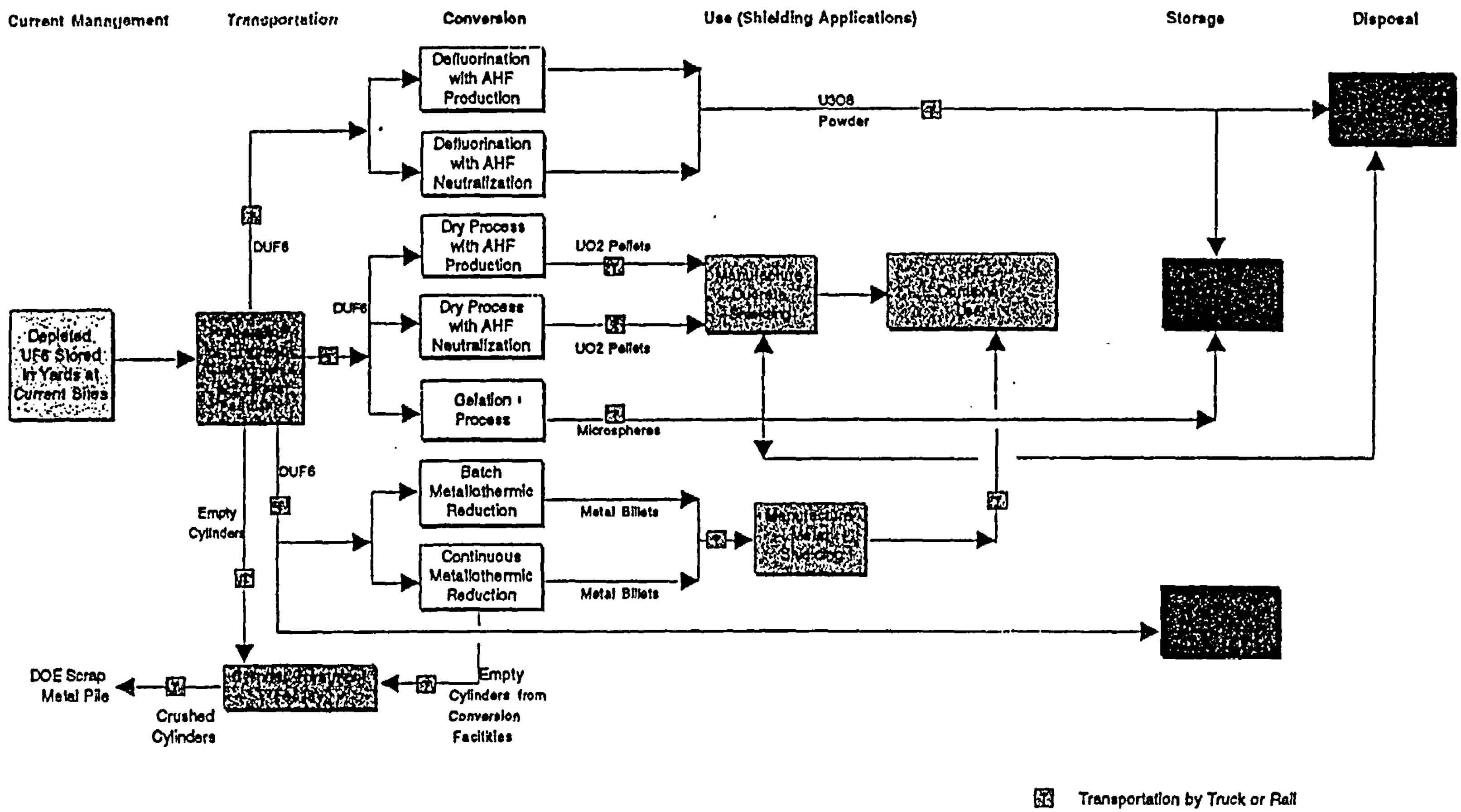


Figure 2.2 No Action Alternative - Current Management Activities Continue through 2039

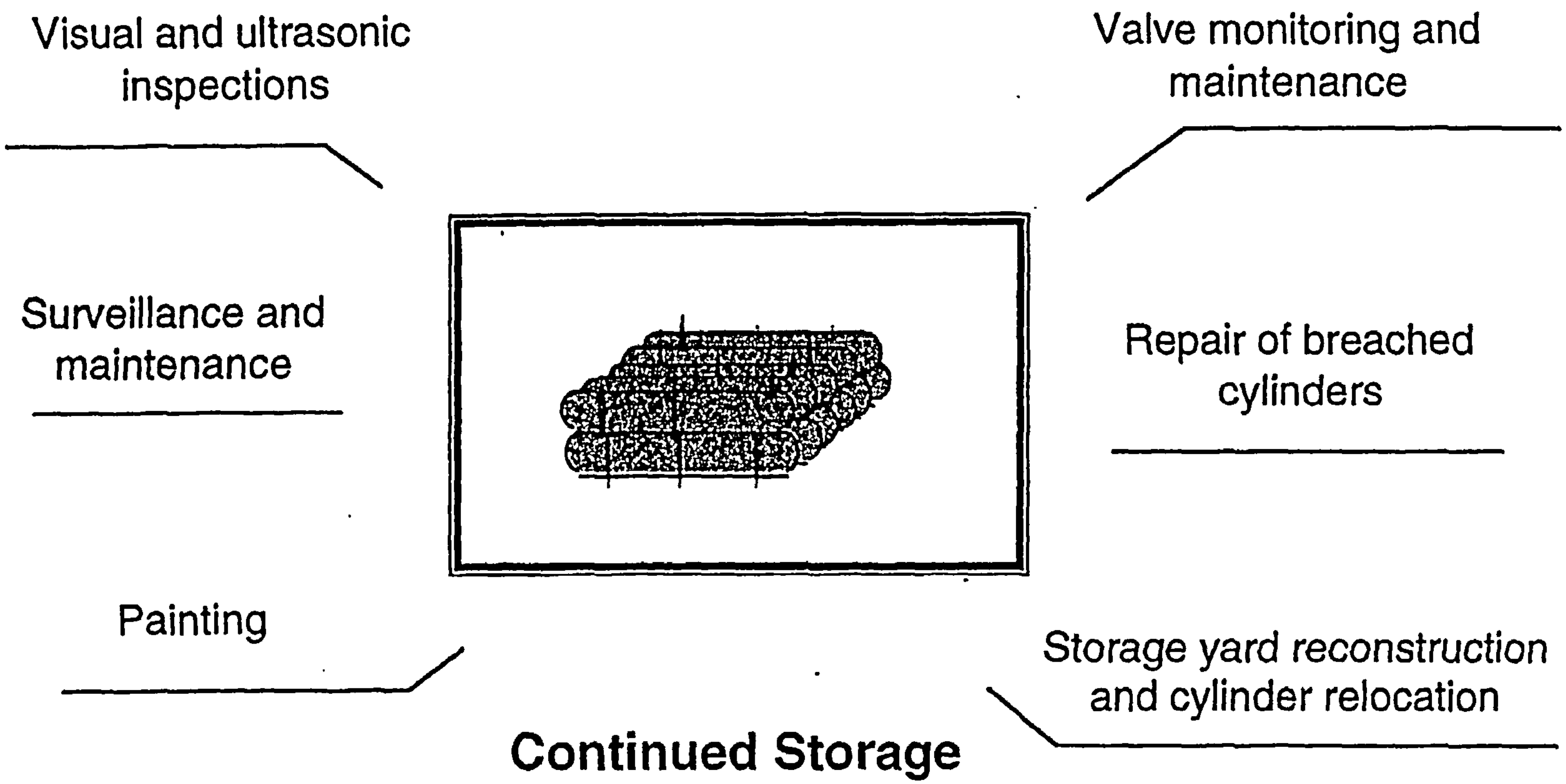


Figure 2.3 Long-Term Storage as UF_6

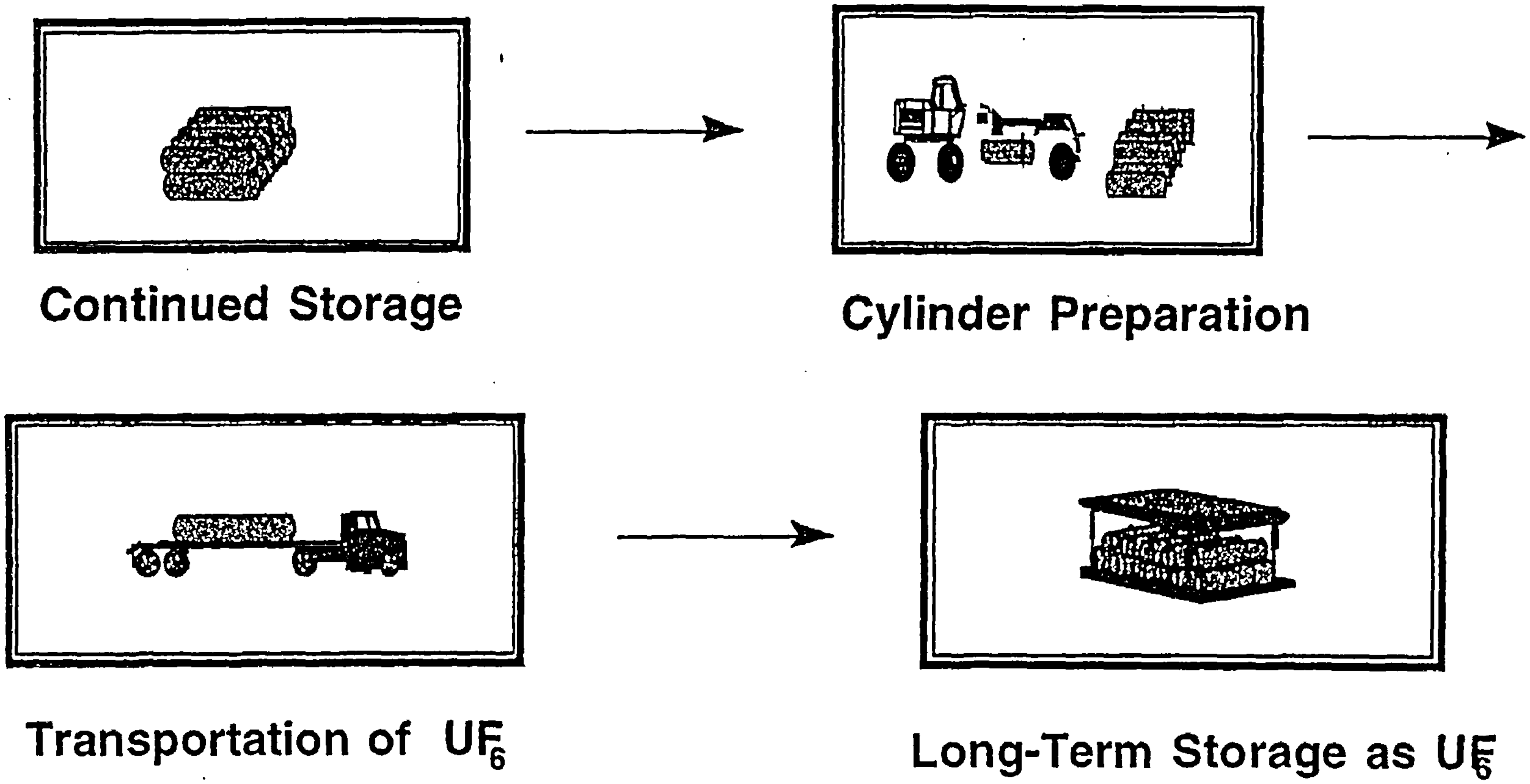


Figure 2.4 Long-Term Storage as Uranium Oxide

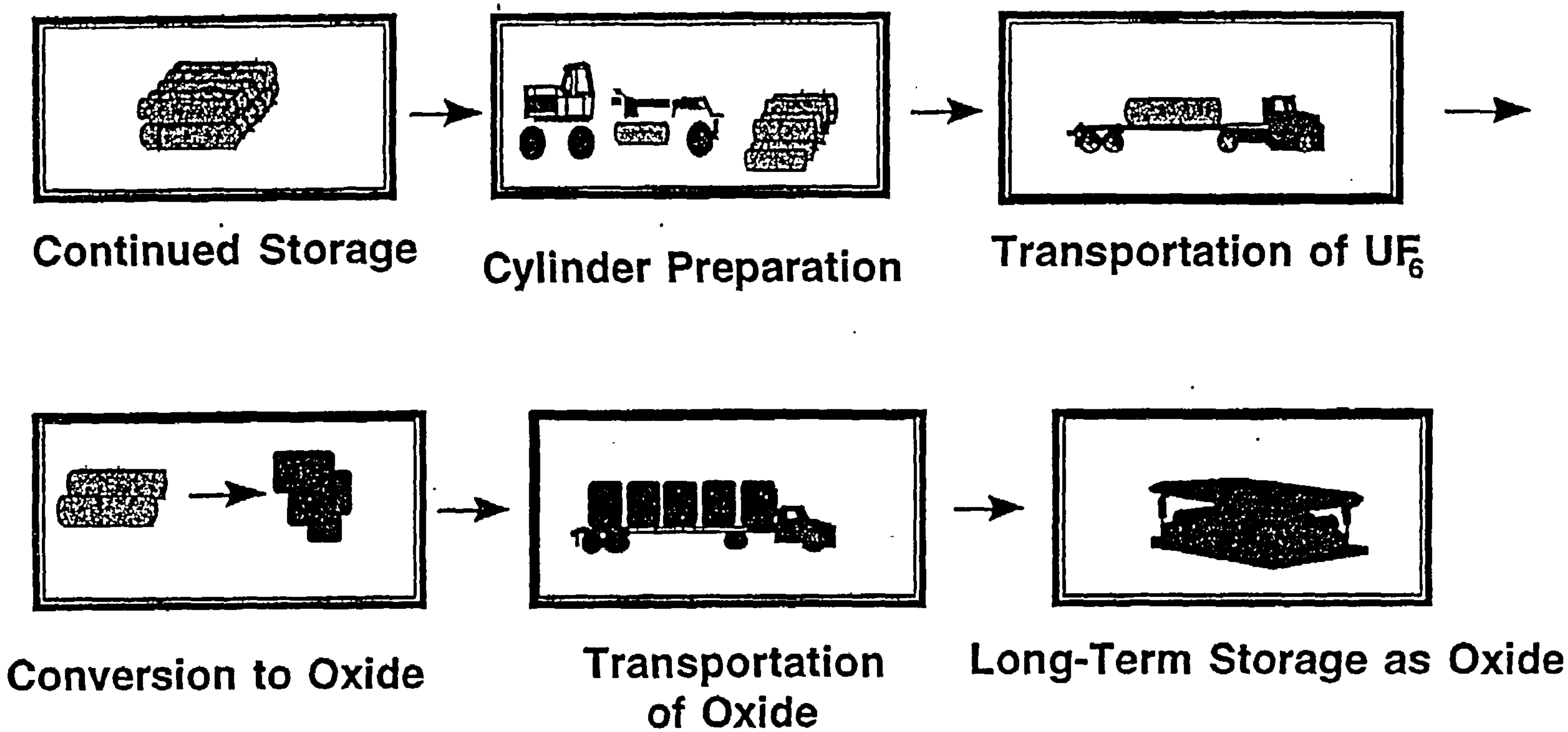


Figure 2.5 Use as Uranium Dioxide in DUCRETE™

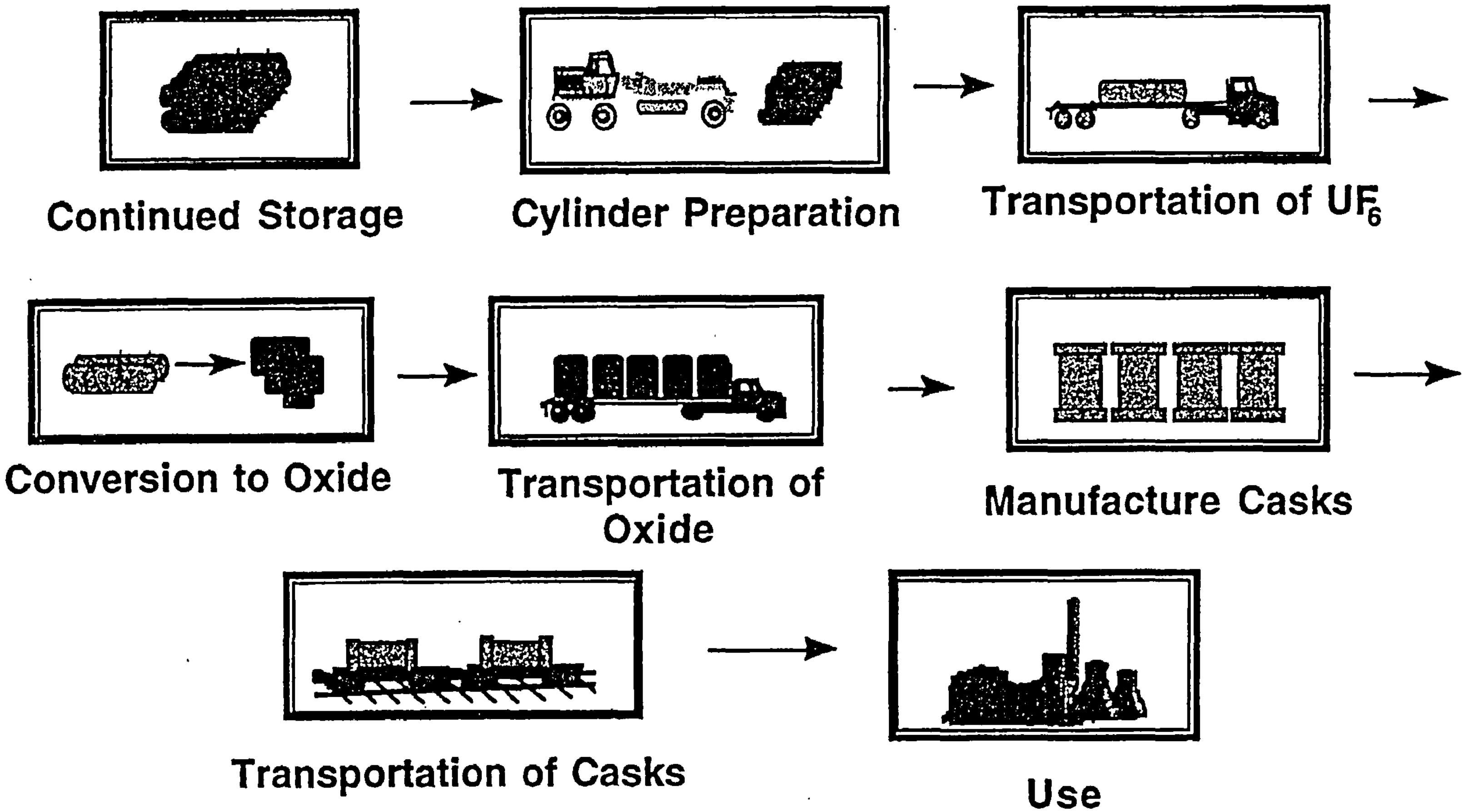


Figure 2.6 Use as Uranium Metal

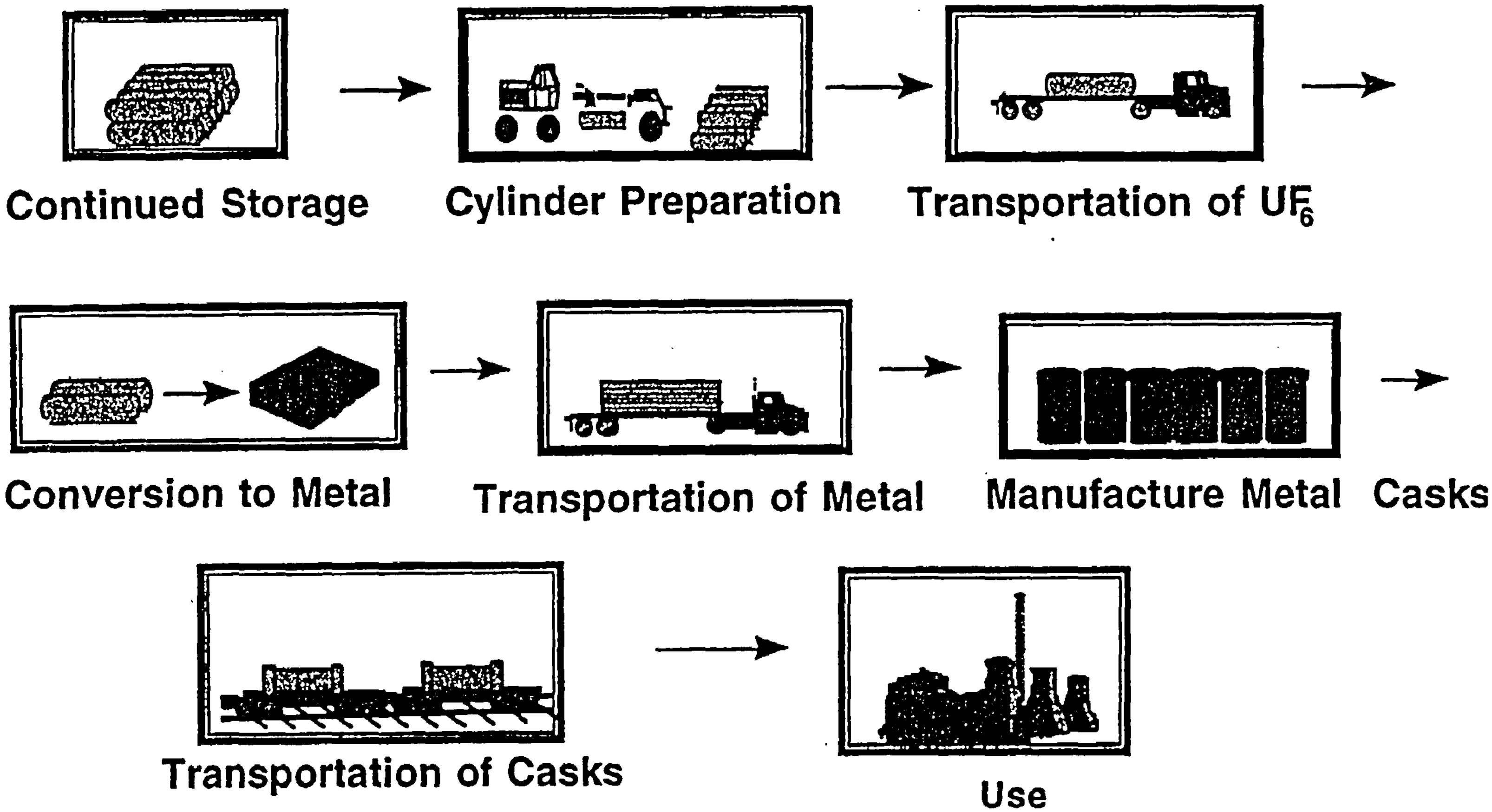
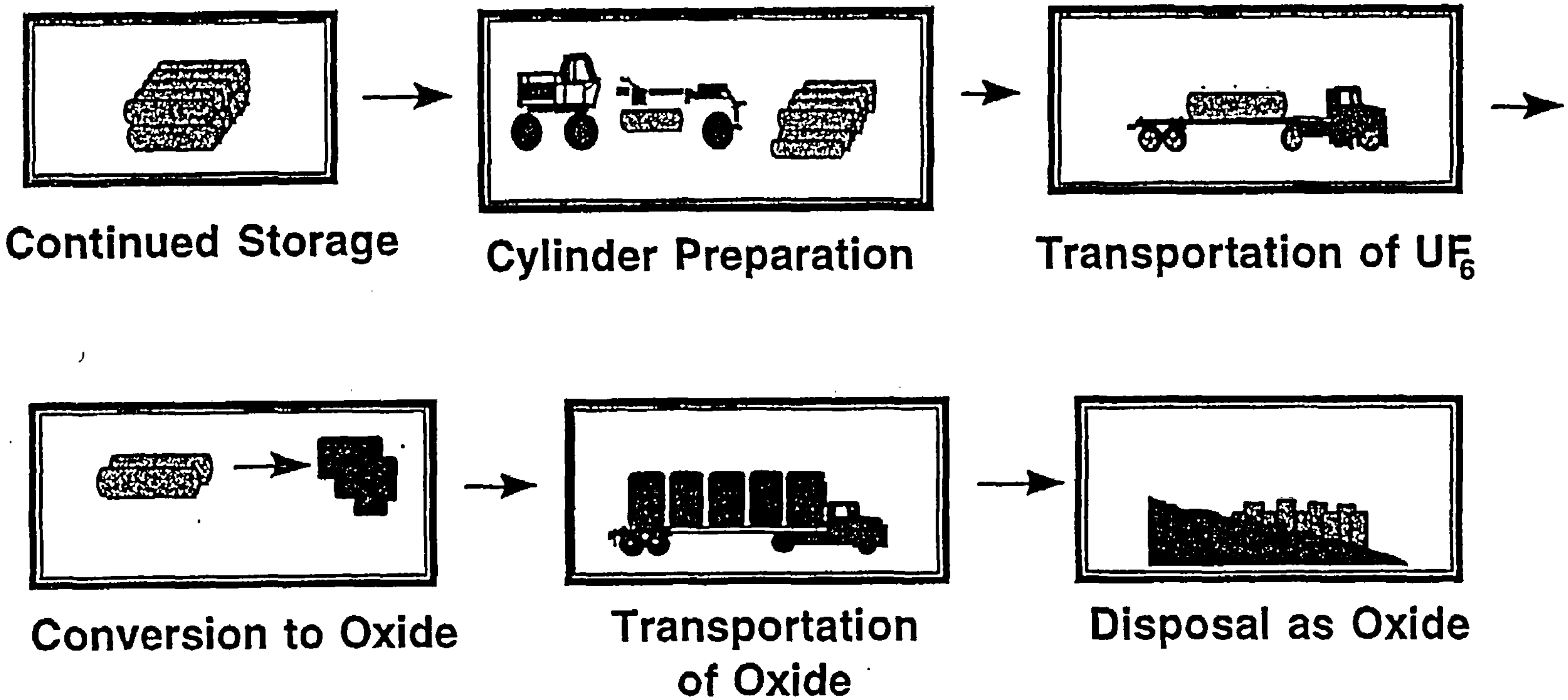


Figure 2.7 Disposal as Oxide



3. COST ESTIMATION METHODOLOGY

3.1 Approach

Costs were developed in a three-phase process. In Phase I, the costs of the primary contributors to capital and operating costs were developed. In Phase II, factors for other life-cycle costs were analyzed. These two phases were performed concurrently. In Phase III, the costs and revenues estimated in Phases I and II were integrated into a computer cost model to determine the life-cycle costs of all the management strategy alternatives being considered.

3.1.1 Cost Estimation for Primary Capital and Operations and Maintenance Costs

Each of the options described in Section 2.1 (i.e., the primary cost contributors) was analyzed as part of the Engineering Analysis Project. The costs were developed in accordance with a cost breakdown structure (CBS) paralleling the work breakdown structure (WBS) used in the Engineering Analysis Project (Lawrence Livermore National Laboratory 1996). Figure 3.1 summarizes the CBS modules and options (see Section 2.4 of the *Engineering Analysis Report* for a discussion of the methodology and the selection of options for in-depth analysis). The options which were analyzed in detail are the building blocks for the alternatives. Figure 3.2 shows the CBS at Level 6 for the U_3O_8 conversion option using the defluorination process with anhydrous HF production.

Costs were developed at least one level below that at which they are reported. These costs were reported in preliminary draft Cost Estimation Reports (CERs) that were prepared according to preset guidelines. Rather than revising the individual CERs to reflect any subsequent changes, the cost model described in Section 3.1.5 is being used to capture updates to the cost estimates.

The capital and operating costs were developed and reported year by year over the life of the project in accordance with the project schedule. A period of 20 years was assumed to disposition the entire depleted uranium stockpile (about 560,000 MT UF_6 in 46,422 cylinders). This corresponds to an annual throughput rate of 28,000 MT of UF_6, or about 19,000 MT of uranium.

A cash flow analysis was prepared to establish life-cycle costs. All costs were estimated in first quarter fiscal year 1996 dollars. In general, a scoping-level combination of vendor quotes, a factored approach based on historical cost data, and a detailed engineering (bottom-up) approach were used in estimating costs. A factored approach was used when historical data were available for cost elements, for example, for the cost per square foot of a particular type of building (e.g., Butler). The total cost was estimated using the size of the structure and the per-square-foot cost factor. A detailed engineering approach begins with a specific facility design, and, from this, estimates are made of the quantities of materials, labor, and other components required. Unit costs were applied to these estimated quantities to prepare the direct cost estimates. Additional costs were estimated using assumptions concerning the type of construction, safety and environmental regulations, production throughput, and other factors.

In Chapter 4, Cost Estimation of Options, costs are reported to the nearest $10,000, resulting in some estimates with five significant figures. A maximum of two significant figures is considered appropriate; however, rounding was reserved for the final totals (Chapter 5, Cost Estimation of Strategies) and is not used on interim results.

Figure 3.1 Cost Breakdown Structure (CBS) to Level 3

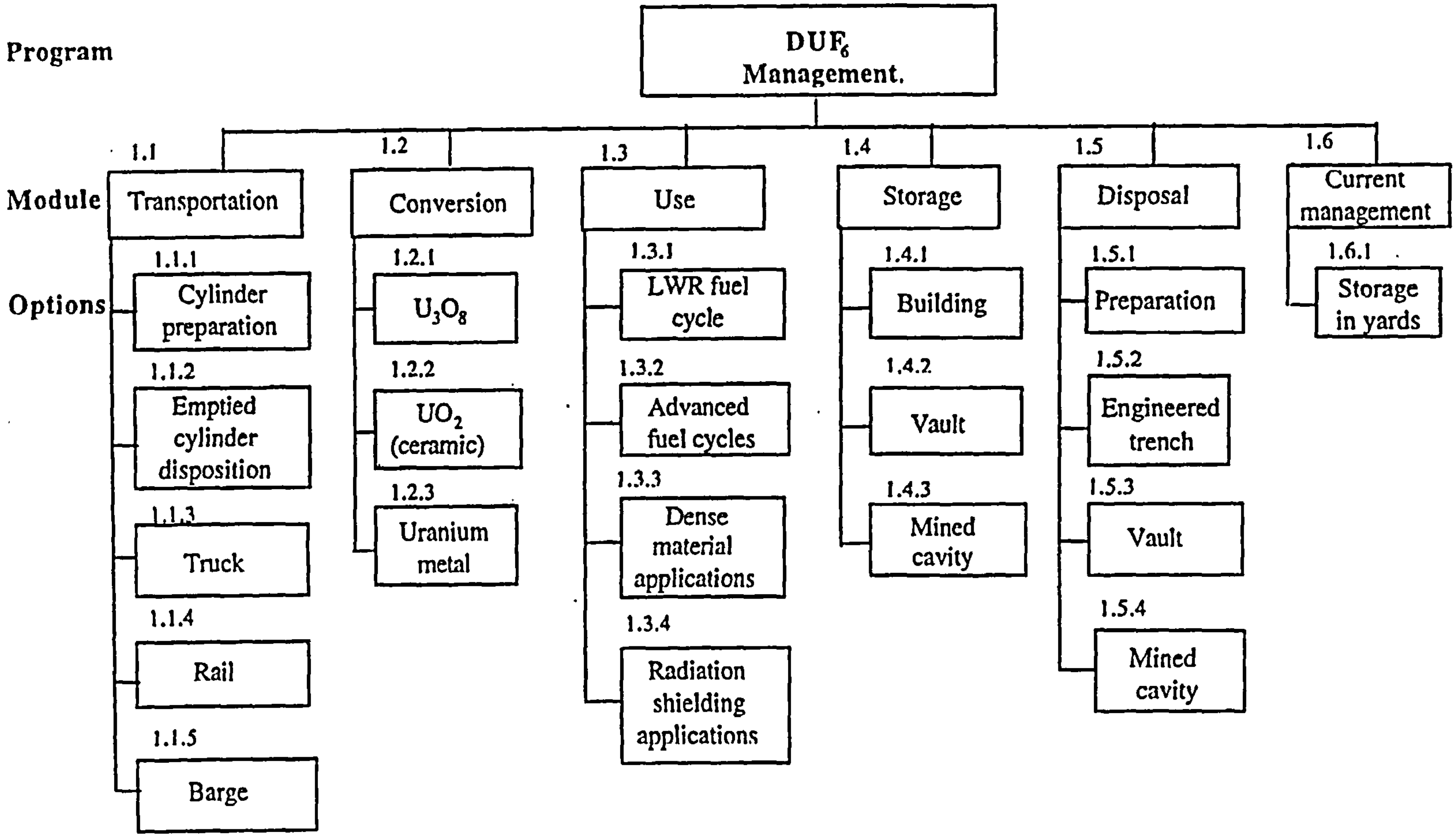
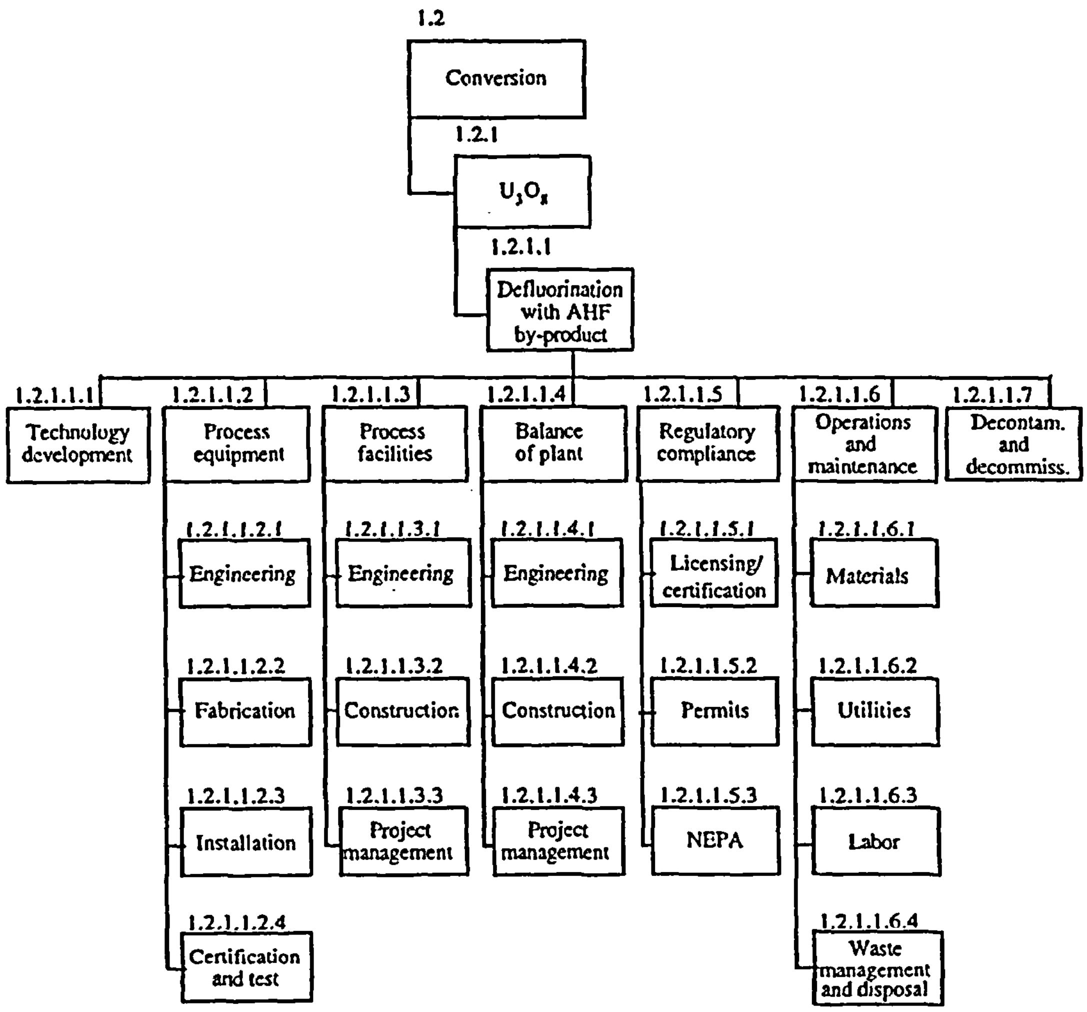


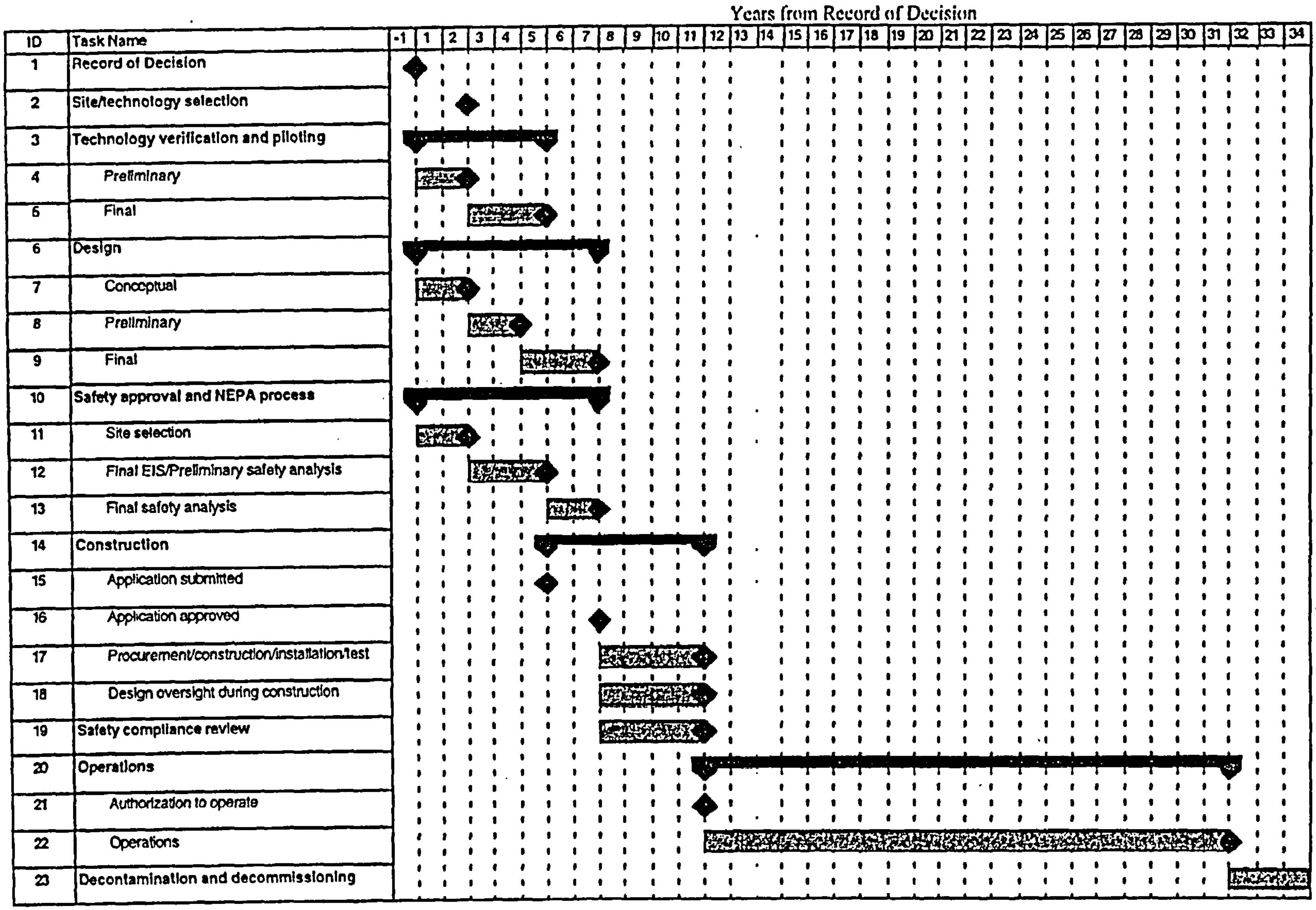
Figure 3.2 Cost Breakdown Structure (CBS) to Level 6 for Conversion to U_3O_8 Using Defluorination with Anhydrous HF Production



3.1.2 Schedule

A generic schedule was assumed for conversion (including empty cylinder treatment) and manufacturing facilities in the program. Schedules have not been differentiated for DOE or privatized facilities at this time. Beginning from the time of the Record of Decision (ROD), technology verification and piloting were assumed to take five years, including preliminary assessments. Simultaneously, design activities and the safety approval/NEPA processes would be proceeding, both of which were assumed to be completed within seven years. Site preparation, facility construction, procurement of process equipment, and testing/installation were assumed to require four years, which would have plant start-up occurring about 11 years after the ROD. Facility operation and maintenance are assumed to begin in the twelfth year and be complete at the end of the thirty-first year of the project. Decontamination and decommissioning are assumed to take three years and start immediately after 20 years of operations and maintenance. The generic schedule is shown in Figure 3.3.

Figure 3.3 Schedule



3.1.3 Basis for Financial Analysis

There are three alternatives for the ownership and operation of the conversion, manufacturing, long-term storage, and permanent disposal facilities and transportation equipment. These alternatives are government, regulated quasi-private (analogous to utility companies), and fully private. What alternative is chosen for ownership and operation has implications for basic project costs and schedules, permitting and licensing costs, facility operating requirements, capital structure of the enterprise, and sources of money and, hence, for cost of funds, profitability requirements, and taxes. These issues are beyond the scope of this *Cost Analysis Report*, whose focus is on how design requirements are translated into costs for a government enterprise.

OMB Circular A-94 Section 4 (OMB 1992) provides guidance for internal Executive branch financial analyses to be submitted to the Office of Management and Budget (OMB). In particular, it addresses federal budget preparation and analyses supporting government decision making regarding projects and programs where measurable costs and benefits extend three or more years into the future. Management of the Department of Energy's depleted UF_6 is an example of such a program. OMB Circular A-94 (Section 5) recommends use of benefit/cost analysis in the form of discounted costs and benefits. The Circular (Section 7) also requires that all costs and benefits be in initial-year dollars (that is, noninflating dollars) and that an inflation-free discount rate be used for this analysis.

In this *Cost Analysis Report*, the different depleted UF_6 management strategy alternatives are evaluated in terms of net present value of all outlays and returns, beginning with technology development and ending with facility decommissioning and decontamination.

3.1.3.1 Reference Case Return Rate

OMB Circular A-94 recommends a value of seven percent per annum (7% p.a.) for reference case analysis (Section 8b). This rate is described as approximating the marginal pretax return rate for investments in the private sector. The use of this return rate can also be supported through examination of return rates in industries similar in nature to those participating in depleted UF_6 management projects. Accordingly, the 7% p.a. value is used for reference case analyses in this *Cost Analysis Report*.

Inflation-free rates are not regularly reported in the financial and business press. A crude correction can be made by subtracting an inflation rate estimate from the reported cost of funds. The March 25, 1996, issue of *Business Week* lists the 1000 largest companies in the United States as measured by their value. Subsets of these data were examined to determine what expectation of return rate the managers and owners may have. The metric used was a pretax "return on invested capital," although other metrics are certainly possible. The results are presented below in terms of minimum, average, and maximum values:

Industry Group	Return on invested capital for 1995 (%) (Min)	Avg.	(Max)
Chemicals (5 companies)	(15.5)	22.2	(29.9)
Manufacturing (13 companies)	(1.2)	14.3	(25.8)
Paper (7 companies)	(3.4)	12.7	(21.3)
Electric utilities (9 companies)	(0)	9.0	(10.0)

Industry groups in the above table were selected as being representative of those which might be interested in participating in depleted UF_6 management strategy activities. Chemical companies have a long history of participation in the DOE missions. Studies comparing industry group characteristics have concluded that uranium enrichment has a structure similar to that of the paper industry. If the depleted UF_6 is managed as a quasi-private enterprise, the electric utility industry would seem to be a reasonable model to use for the purpose of estimating profitability expectations.

Assuming long-term stability of the U.S. economy, the future inflation rate may be in the range of 2.5-3.0% p.a. In order to estimate the inflation-free return rate, a number in this range would need to be subtracted from the return on invested capital in the preceding table. If this is done, the average inflation-free return rates range from 10-19% p.a. for private industries which might be similar in nature to those participating in depleted UF_6 management projects and 6% p.a. for a regulated industry.

It is believed that these examples support the OMB Circular A-94 recommendation of a reference case value of 7% p.a. if one remembers that 7% does not cover all businesses' requirements for return on investment. In fact, the 7% p.a. return rate seems appropriate for a licensed monopoly (such as a utility) where government regulation, not free competition, protects the consumer from overcharging.

3.1.3.2 Return Rates for Sensitivity Studies

It is important to look at the financial analysis from a sensitivity study perspective to ensure that the ranking of strategies does not depend strongly on the choice of discount rate. In Chapter 6, the sensitivity of results is tested by reporting net present values of the alternative strategies at 4% and at 15% p.a., as well as at the reference case rate of 7% p.a. The purpose of the next paragraphs is to establish the reasonableness and rationale for 4% and 15% p.a. sensitivity study return rates.

The table in Section 3.1.3.1 shows the impacts of investment risk certain industries have become accustomed to as they pursue their customary lines of endeavor. As indicated, there is a range of returns within an industry group which depends on the details of the various enterprises and the ability of the managers to forecast and prepare for the future. Additionally, not shown in the table are the temporal trends or business cycles to which several industry groups are subject and which affect year-to-year profitability. In this latter sense, profit margins for 1995 were about 25-40% better for the industry groups shown than were those of 1994.

The data in the preceding table support an upper sensitivity return rate in the neighborhood of 15% p.a. for conventional private industries which operate in a competitive market where return rates do not have to be restricted by government entities to protect consumers. The lower bound for sensitivity calculations can be derived from an assumption that depleted UF_6 management will be a government project since the material was government-generated and now is government-owned. The guidance of OMB Circular A-94 (Appendix C) is to use 3% p.a. for government projects extending for 30 years.

The business literature provides other measures of return rate expectations. Among these are the bank prime rate and U.S. Treasury bond rates. The March 13, 1997, *Wall Street Journal* quotes the following values for these metrics:

Prime rate (set 2/1/97)	8.25% p.a.
U.S. Treasury bond rate	
2 year	6.08% p.a.
5 year	6.42
10 year	6.58
30 year	6.87

The prime rate indicates a demand for an inflation-free commercial return rate of 5.25-5.75% p.a. when the investment has minimal risk. However, its use is inappropriate for the purpose of developing a lower bound return estimate where the project is postulated to be government owned and operated. For this case, U.S. Treasury bond rate data are appropriate because the government assumes all the risk. The data in the table above imply an inflation-free return rate of about 4% p.a. for a lower bound government project, where there is minimal business risk. For this analysis we have chosen the 4% p.a. figure as the lower sensitivity value.

3.1.4 Other Life-Cycle Costs

Other life-cycle costs and revenues were the subject of their own special studies. Examples include market surveys to determine the market price for the anhydrous HF and CaF_2 by-products produced from conversion (described in Section 4.2.2). An estimate of the cost of regulatory compliance was another study (described in Section 3.2.4). Cost estimates for both DOE and Nuclear Regulatory Commission (NRC) requirements under each option were estimated. The more costly DOE requirements were integrated into the computer model described in Section 3.1.5 and included in the cost estimates for each option.

3.1.5 Integration of Costs

A computer model was developed to integrate the primary capital and operating costs and other supporting costs and factors. Unit costs and facility size were used as a base, to which were added appropriate costs for installation, project management, taxes, contingency, and other factors; site preparation and utility costs; and decontamination and decommissioning costs. Cost factors and other cost assumptions described below are input variables in the cost model. As such, they may be revised as necessary.

3.2 Cost Basis

The preoperational, capital, operating, and other life-cycle costs are described in the remainder of this section. A median cost reflecting contingency based on a 50% probability of overrun and a 50% probability of underrun is reported. Stated another way, there is a 50% likelihood that the as-built costs would be either greater or less than those presented.

3.2.1 Technology Development

The cost of technology development includes the costs for verification and piloting necessary before detailed design and engineering. Design work performed prior to Title I design and funded out of the DOE operating or new owner's budget falls in this category. Usually, this work is performed by an architect/engineering (A/E) firm or by the resident engineering staff at a management and operations (M&O) contractor site. Such a design is usually the first "bottom-up" design using take-offs from drawings and equipment specifications and includes a cost estimate. Technology development is shown on the generic schedule (Figure 3.3) as technology verification and piloting during years 1-5.

Initial projections of technology development costs, including pilot scale testing, are provided in the cost tabulations found in subsequent chapters. The cost estimates were primarily based on engineering judgment, following review and ranking of the subsystem uncertainties. The focus is on relative costs. The reader is referred to Chapter 3 of the *Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride*, Rev. 2. It was implicitly assumed that the development and testing would be conducted in existing facilities capable of handling large quantities of depleted uranium and having suitable infrastructure.

Definitive engineering development costs will be established in a subsequent phase of the Depleted UF_6 Management Program.

3.2.2 Capital Costs

This section defines the terminology used in the discussion of facility capital costs, lists the components of a capital cost, and outlines the approaches used to estimate these costs.

3.2.2.1 Architect/Engineering

Architect/engineering design costs were estimated at 25% of total field cost. This includes conceptual, Title I, Title II, and Title III design and engineering.

Title I is the preliminary design and is usually the first line-item funded design effort for a facility. It includes detailed drawings, bills-of-material, and craft labor requirements. A Title I cost estimate is usually also produced. An architect/engineering firm is often used for this level of design effort. The design at this point will be site-specific. Title II design produces the final preconstruction drawings, bills-of-material, and other specifications. The same A/E firm as for Title I design is often used. Title III is engineering that takes place primarily during construction and involves verification that the Title II final design is being implemented. Inspection activities and quality assurance (QA) are included in this category.

Architectural and engineering costs are incurred during the design period shown on the generic schedule. The A/E costs for process equipment, process facilities, and balance of plant are found at CBS Level 6. Conceptual design costs are 10% of total A/E cost spread evenly over the first two years. Eighty-five percent of the remaining 90% of A/E costs

(76.5% of the total A/E cost) was allocated to preliminary (years 3-4) and final (years 5-7) design. The final 15% of the remaining 90% (13.5% of the total A/E cost) was allocated to the design oversight of construction (years 8-11)

3.2.2.2. Construction

The initial site selected for costing purposes was a hypothetical green field site in Kenosha, WI. This is the standard description for an east/west central site and is typical for electric power generation facilities, having access to water and rail transportation. It was used for the engineering analysis and establishes the basic manual labor rates and state sales tax.

Davis-Bacon manual labor rates for Kenosha, WI, the Workers Compensation Insurance rates for Tennessee, and a standard 40-hour work week were used, plus an allowance of 1% for casual overtime. If costing involved an existing or a different site, Davis-Bacon manual rates for that specific area were used. For example, labor rates at Portsmouth, OH, Paducah, KY, and Oak Ridge, TN, were used to estimate the cost of continued storage of depleted uranium hexafluoride in yards.

For process equipment cost element (CBS Level 5), capital costs for materials and tax on materials are captured under fabrication at CBS Level 6, as shown on Figure 3.2. After engineering and process equipment are subtracted, the remaining capital costs for process equipment are captured under installation at CBS Level 6. For process facilities and balance of plant (CBS Level 5), these costs are captured under construction at CBS Level 6.

Direct construction costs include the cost of craft labor, construction materials (such as concrete forms, rebar, concrete, structural steel, piping, electrical raceway and cable) and installed equipment (such as process equipment and service equipment). Costs were estimated as follows:

Cost Element	Basis, Assumption, Value Range
Major equipment:	Vendor quotes; historical data; or a factor approach based on complexity, size, mass, and technical maturity
Process support equipment:	Same as major equipment or percentage of major equipment cost, depending on the type of support equipment
Process support systems:	Actual cost or percent of major equipment cost, depending on the support system
Major facilities:	Quantity take-offs or "bottom-up" estimates or factored approach
Support facilities:	$/square foot or $/cubic foot, depending on the classification of the facility
Facility support systems:	$/unit or percent of total facility cost, depending on type of facility support system
State sales tax:	Sales tax on materials (including distributable field costs on materials) - 6%

Indirect costs are distributables (general conditions), overhead, and profit. These include support to direct construction for temporary construction facilities, construction equipment, construction support, field office expenses, and craft supervision. Construction facilities include on-site offices, warehouses, shops, change rooms, construction roads, construction parking lots, etc. Construction support includes such items as construction tools and consumables, safety equipment, material handling and warehousing, and general cleanup. These costs were estimated as follows:

Distributable field (general conditions) costs:	Distributable field costs for materials are 28% of the direct labor costs. Distributable field costs for labor are 75% of the direct labor costs.
Contractor's bond:	1% of total contractor's contract value
Contractor's overhead and profit:	5% for materials and 15% for labor, taken as a percentage of both total direct costs and distributable field costs.

Initial spares are major and crucial extra equipment items purchased out of the project capital budget. These are items needed to ensure process operation in the event of the failure of a major piece of installed equipment. The nature and cost of these items are technology-dependent.

Initial spare parts:	10% of process equipment, exclusive of piping, instrumentation, and installation

3.2.2.3 Balance of Plant

The balance of plant CBS includes the costs of site improvements, utility buildings, services, and support buildings. Site improvement costs include roads, parking areas, fencing, landscaping, and railroad spurs. Support buildings include an administration building, a utility building, a site warehouse, maintenance shops, an entry control building, and sanitary and industrial waste treatment facilities.

Once a site for a facility is recommended, it must be certified that the site geology, infrastructure, and meteorology are capable of safely accommodating the facility and any wastes or emissions generated therefrom. For geologic disposition options, this can be a lengthy and expensive step. Much of the work involves environmental and geologic sampling and documentation of findings. Although no specific sites were selected during Phase I of the Depleted UF_6 Management Program, generic site selection and site qualification costs were developed.

3.2.2.4 Cost Estimating Contingencies

Engineering contingencies which reflect the level of the preconceptual designs, the engineering data available, and the experience base were determined for the various options. It was assumed that a development program would verify process feasibility, demonstrate successful equipment operation and integration, and generate engineering data for scale-up to production size equipment. These cost estimating contingencies were applied to capital costs as follows:

- Process and manufacturing facilities: 30%
- Balance of plant: 20%

- Process and manufacturing equipment: variable (~30-50%, depending on option)

The variable process and manufacturing cost estimating contingencies do not consider process feasibility or performance risk, which is described in Chapter 6 (the sensitivity analysis) of this report. In particular, factors that indicated a higher process and manufacturing contingency included (1) little or no operational experience with similar processes or equipment, (2) first-of-a-kind and custom-designed equipment, (3) uncertainty regarding the selection of materials of construction, and (4) conceptual nature of equipment or lack of good definition. Factors that indicated a lower process and manufacturing contingency included (1) industrial experience with similar processes and equipment, (2) standard unit operations with well-recognized design methods, and (3) standard or off-the-shelf equipment.

3.2.3 Capital Costs - Project Management

For government-owned facilities, DOE usually hires a construction manager (normally an A/E firm) to handle the subcontracting of craft labor and to interact with the design A/Es and equipment vendors.

Construction management:	10% of contractor's field cost after taxes
Project management:	6% of total capital costs, including both direct and indirect costs

3.2.4 Regulatory Compliance

Scoping-level estimates were developed as a separate study for the cost of permitting, licensing, and environmental documentation under both public and private ownership and operation. The following were considered:

- Atomic Energy Act/Nuclear Regulatory Commission (NRC) regulations
- Department of Energy Orders
- Clean Air Act
- National Environmental Policy Act
- Resource Conservation and Recovery Act
- Clean Water Act
- Packaging and Transportation of Radioactive Material/NRC regulations
- Hazardous Materials Transportation Act
- Safe Drinking Water Act
- Emergency Planning and Community Right-to-Know Act

Under the Atomic Energy Act, DOE Orders would apply to DOE-owned facilities while NRC regulations would apply to privately owned commercial facilities. Both costs were estimated, but only costs for regulation under DOE Orders is included in the *Cost Analysis Report* since this is the more costly set of requirements.

Regulatory compliance includes preparation of the site-specific EIS (which follows the more generic PEIS) and state, local, and federal permits related to air and water quality. Construction permits are also included in this category, which covers the legal and technical work needed to obtain the NRC license required to begin construction. Some technical work, such as safety documentation, would be performed by vendors, new owners, or national laboratories.

3.2.5 Operations and Maintenance - Materials

Operations and maintenance costs are captured at Level 5 of the CBS.

Chemical or feed costs:	Cost of consumable materials for process operations such as chemicals, cements, and additives are based on vendor quotes, *Chemical Market Reporter* magazine, or similar sources.
Facilities and equipment maintenance and spares:	4% of the total direct facility capital cost

3.2.6 Operations and Maintenance - Labor

Direct Operations Staff

This category includes salaries plus fringe benefits for those persons directly associated with operations, such as chemical operators, foremen, and technicians, plus their line supervision. Clerical and health physics support in the process area are also included here.

Number of shifts:	One, two, or three, depending on engineering design
Breakdown of staffing and cost/person-hour:	Davis-Bacon wage rates for Kenosha, WI, for nonexempt employees and current national average wage rates for exempt employees
Production rate:	Based on 20 years of operation, 28,000 MT of depleted UF_6 per year
Plant availability:	80% of operating days/year, unless engineering data reports specifically prescribe otherwise

Direct Maintenance Staff

This category includes salaries plus fringe benefits for those persons directly associated with maintenance.

Indirect Staff

This category includes salaries plus fringe benefits for other personnel needed to run the facility in a safe and environmentally compliant manner meeting all federal, state, and local regulations. Among the indirect staff would be medical personnel; engineers; research and development (R&D) staff (for post-startup, process improvement R&D); human resources personnel; fire fighters; stores clerks; travel clerks; in-house environment, safety, and health (ES&H) oversight personnel; and the secretarial pool. Some of these functions may be shared with other facilities on a DOE reservation and their costs allocated on a fair basis.

Prior to commencing normal operations, the operator of a facility (presumably an M&O contractor/owner) must become familiar with the facility processes. Technology and

information transfer from vendors to the M&O contractor/owner is required. DOE Orders and NRC requirements also necessitate extensive training of M&O staff, not only on technical operations, but also on the ES&H aspects of facility operations. Start-up costs were estimated to be 65% of the first year's operating labor, incurred the year before operations begin.

Current regulatory regimes require complete documentation of operational procedures prior to facility start-up. As part of this activity, manuals for various process equipment items must be prepared, which may involve both vendors and M&O contractors/owners. The facility project office must also prove to the NRC or DOE that the facility is ready to commence operations in a safe and environmentally benign manner. Considerable time on the part of the contractor and regulatory staff may be required to prepare for and carry out these reviews.

3.2.7 Operations and Maintenance - Utilities

Utilities include annual costs for electric power, natural gas, fuel oil, water, purchased steam, telephones, and other nonelectric utilities. Utility costs depend on the location of the facility.

Utilities and services costs:	10% of total operating labor or based on current rates and power requirements, whichever is greater

3.2.8 Operations and Maintenance - Waste Management and Disposal

Depending on the characterization of wastes by engineering studies, the cost of disposal will be determined by the approaches defined below. Packaging and transportation costs will be added where applicable. Disposal costs were based on Murray (1994). The cost per unit volume for waste disposal is an input variable in the cost model and may therefore be modified.

<u>Mixed Waste</u>

Disposal costs for mixed (radioactive/hazardous) waste were reported in this category. A cost of $100/cubic foot was used.

<u>Hazardous Waste</u>

Disposal costs for hazardous waste were reported in this category. A cost of $20/cubic foot was used.

<u>Low-Level Radioactive Waste</u>

Waste of this type is sent to DOE sites or special burial sites covered under regional LLW compacts. The cost is typically levied on a $/cubic foot basis. A cost of $100/cubic foot was used.

<u>Nonhazardous Waste</u>

Nonhazardous sanitary liquid wastes generated in facilities are transferred to an on-site sanitary waste system for treatment. Nonhazardous solid waste disposal costs (e.g., CaF_2) are assumed to be $2/cubic foot.

3.2.9 Revenues

Some of the conversion processes result in marketable by-products, such as the anhydrous hydrofluoric acid (AHF) produced in the defluorination process and the calcium fluoride from the neutralization process. The use module in the engineering analysis anticipates direct use of the depleted uranium shielding forms. These products or by-products will generate revenues which partially off-set the conversion and manufacturing costs. An initial market survey was conducted to determine the size of markets for the major by-products (AHF and calcium fluoride) of the various conversion processes. Issues addressed included annual sales of product, price, growth or reduction forecast for the markets, and the capacity of the market to absorb additional supply without undue effects on price. The effect of shielding cask values is presented in Section 6.1.3, while the revenue from sale of AHF and CaF_2 is presented in Section 4.2.2.

3.2.10 Decontamination and Decommissioning (D&D)

It was assumed that a DOE M&O contractor and perhaps an A/E would shut down and decontaminate the facility and remove contaminated and junk equipment. It was assumed that facility demolition would not be required. The D&D cost includes disposal of contaminated or junked equipment at licensed disposal sites.

Decontamination and decommissioning:	10% of the total costs for process equipment, process facilities, and balance of plant (i.e., the plant capital cost)

This estimate is based on historic and projected D&D costs for facilities with similar complexity, size, and hazardous waste characteristics.

3.2.11 Transportation

All costs for transportation of depleted uranium were tabulated. An engineering cost analysis of transportation alternatives was conducted and a submodel developed to assess the cost per unit quantity per unit distance traveled and the loading/unloading operation performed.

3.2.12 Exclusions

The following items have been excluded from the estimates during Phase I, but may be included during Phase II of the Program, when there is a basis for defining these costs:

- Fees earned by M&O contractors
- Royalties to third parties
- Payments in lieu of property taxes
- DOE oversight costs
- Cost of land

Land requirements for each option were estimated in the *Engineering Analysis Report*. The cost of land was excluded, however, because land prices are highly dependent upon location, which will be determined in a later phase of the Program. In addition, it would neither discriminate between alternatives nor significantly affect the total cost of an alternative, as illustrated in the following paragraph.

The estimated land area required for the conversion options ranges from about 13 to 20 acres. Assuming that land in an industrial area costs $5,000 per acre, this would add up to $100,000 (a few hundredths of a percent) to the cost of implementing a conversion option. Estimated land requirements are greater for the use, storage, and disposal options than for the conversion options. Shielding fabrication facilities occupying 90 acres would add about $450,000 (again, a few hundredths of a percent) to the total cost. Land requirements for storage facilities are estimated to range from 74 acres for mined cavity storage of UO_2 to 212 acres for vault storage of U_3O_8 with corresponding land costs of $370,000 to $1,060,000, based on a unit cost of $5,000 per acre. Inclusion of the cost of land would add less than one-half of one percent to the total cost of each option and would be insignificant when comparing storage options (e.g., building, vault, or mined cavity). A similar comparison may be made for disposal options, where the greatest land requirement is for disposal of grouted U_3O_8 in a mined cavity (1141 acres). Including the cost of land for this option would increase the cost by less than one-half of one percent.

4. COST ESTIMATION OF OPTIONS

All costs reported in this document are median costs (50% probability of overrun and 50% probability of underrun) and are given in millions of first-quarter 1996 dollars discounted to the beginning of the project. The discount rate used for the reference case was 7% p.a.

4.1 Transportation

Transportation costs include the following elements:

- Preparation of depleted UF_6 cylinders which meet DOT requirements (i.e., conforming cylinders) for shipment from the three sites to a conversion or storage facility
- Preparation of depleted UF_6 cylinders which do not meet DOT requirements (i.e., nonconforming cylinders) for shipment from the three sites to a conversion or storage facility
- Treatment of emptied cylinders
- Loading, shipping, and unloading of depleted UF_6, emptied cylinders, U_3O_8, UO_2, uranium metal, uranium metal shields, and oxide (DUCRETE™) shields

Cost for shipping other materials such as input reagents for chemical conversion processes (e.g., ammonia, sodium hydroxide, hydrochloric acid) and output by-products (e.g., AHF) are included in the cost of purchasing the reagents or in the revenues generated from selling the by-products.

4.1.1 Preparation for Shipment

Preparation for shipment includes the cost of preparing conforming cylinders plus the cost of preparing nonconforming cylinders. The preparation cost for the latter is the cost of placing nonconforming cylinders in cylinder overcontainers or the cost of transferring depleted UF_6 from cylinders that no longer meet DOT requirements to new or conforming cylinders.

The number of cylinders that will not meet transportation requirements over the shipping time frame is not precisely known. The costs for preparing the cylinders for shipment are based upon the reference case of approximately 29,000 nonconforming cylinders and 17,000 conforming cylinders. Other cases are presented in Section 6.2.1.

The cost of preparing conforming cylinders for shipment is presented in Table 4.1. Tables 4.2 and 4.3 present the costs of the two options for preparing nonconforming cylinders for shipment, the cylinder overcontainer option and the transfer facility option. The overcontainer option has a much lower estimated cost because process facilities are not necessary and the operations and maintenance activities are simpler and therefore less costly. However, if development and fielding of an overcontainer (which currently does not exist) is adversely impacted by changes in transportation regulations or other factors, the transfer facility provides another option for preparing nonconforming cylinders for shipment.

Three facilities would be required for the transfer option—one at Paducah for transferring 19,200 cylinders, one at Portsmouth for transferring 5,200 cylinders, and one at K-25 for transferring 4,683 cylinders. Table 4.3 shows the combined cost for the three transfer facilities. The costs for the transfer facility option were evaluated by combining the costs

of engineering development, process equipment, process facilities, balance of plant, regulatory compliance, operations and maintenance, and decontamination and decommissioning.[2] Process facilities for the transfer facility include the engineering and construction of a two-story reinforced concrete process building to house autoclaves and other process equipment. Most of the transfer facility process building is special construction with area perimeter walls and ceilings assumed to be 1-ft thick concrete, interior walls assumed to be 8-in. thick concrete, and base mat assumed to be 2-ft thick concrete.

4.1.2 Treatment of Emptied Cylinders

Most of the management strategy alternatives involve removing the depleted UF_6 from the cylinders and converting it to another form, which would generate 46,422 emptied cylinders for disposition. Transfer of the depleted UF_6 into new or conforming cylinders for future storage is another option requiring treatment of emptied cylinders. A preconceptual design for a stand-alone facility for removal of the depleted UF_6 heel from the emptied cylinders is included in the *Engineering Analysis Report*. After the heel is washed from the cylinders, the wash solution is neutralized for disposal and the cylinders are crushed for shipment to DOE scrap metal facilities.

The qualitative and quantitative impacts of collocating the treatment facility with either a metal or oxide conversion facility were analyzed. The collocation would lead to a significant reduction in the required infrastructure, including labor, storage yards for temporary storage of incoming/outgoing emptied cylinders, support buildings, roadwork, grounds, and piping. In addition, the cylinder treatment function would become a processing module within the conversion facility. Table 4.4 presents the incremental costs for integrating the cylinder treatment function into a conversion facility. The estimates for a treatment facility collocated with an oxide conversion facility are about one-quarter the stand-alone costs, while the estimate for a treatment facility collocated with a metal conversion facility are about one-third the stand-alone costs. The cost of a collocated treatment facility is the basis for emptied cylinder disposition costs for the management strategy alternatives.

4.1.3 Loading, Shipping, and Unloading

Loading, shipping, and unloading full depleted UF_6 cylinders, emptied depleted UF_6 cylinders, drums of U_3O_8, drums of UO_2, boxes of uranium metal, uranium metal shields, and oxide (DUCRETE™) shields are included in this cost element. Table 4.5 and Figure 4.1 compare the shipping costs, including loading and unloading, by truck and rail for all the management strategies. Other than shipments originating from the current storage sites, origins and destinations are unknown at this time. For the reference case, a distance of 1000 km was assumed for all shipments. Other cases are considered in Section 6.1.2.

Estimated costs per kilometer traveled and for loading and unloading are lower for truck than for rail ($1.79/km, $100/load, and $100/unload per truckload versus $1.86/km, $1000/load, and $1000/unload per railcar). However, at the assumed distance of 1000 km, the total cost of transport is lower by rail. In general, more material can be placed on a railcar than a truck (approximately a factor of 3 by weight), resulting in a lower cost per kilometer per kilogram of material moved. For distances greater than around 500 km, this outweighs the higher loading/unloading costs and rail is less expensive, but for shorter

[2] Due to the discount effect, costs occurring late in the campaign, such as decontamination and decommissioning, appear to be quite small compared with those such as technology development, which occur early in the campaign.

distances, truck transport would have the lower costs. It is noted that rail costs are influenced by location more than trip distance and therefore have a much higher associated uncertainty than truck transportation costs since locations have not been determined.

4.1.4 Total Transportation Costs

The total transportation costs are presented in Tables 4.6 and 4.7 and are computed as the sum of the costs described in Sections 4.1.1 through 4.1.3. Table 4.6 and Figure 4.2 present the estimate for the low-cost transportation options (i.e., overcontainers for nonconforming cylinders and rail for transport mode). Table 4.7 and Figure 4.3 present the estimate for the high-cost transportation options (i.e., a transfer facility for nonconforming cylinders and truck for transport mode).

Table 4.1 Cost Breakdown (in Millions of Dollars) for Preparation of (17,339) Conforming Cylinders for Shipment

Inspection and retrieval equipment	
Engineering	0.17
Fabrication	1.39
Certification	0.07
Subtotal	1.63
Handling fixtures	
Engineering	0.06
Fabrication	0.47
Certification	0.02
Subtotal	0.55
Shipping fixtures	
Engineering	0.02
Fabrication	0.16
Certification	0.01
Subtotal	0.19
Facilities	
Engineering	0.00
Construction	0.00
Project management	0.00
Subtotal	0.00
Regulatory compliance	1.13
Operations and maintenance	
Materials	1.64
Utilities	0.01
Labor	44.27
Waste Management & Disposal	0.19
Subtotal	46.11
Decontamination & decommissioning	0.00
TOTAL	49.61

Table 4.2 Cost Breakdown (in Millions of Dollars) for Preparation of (29,083) Nonconforming Cylinders for Shipment - Overcontainer Option

Engineering Technology	0.82
Inspection and retrieval equipment	
Engineering	0.23
Fabrication	1.93
Certification	0.09
Subtotal	2.25
Overcontainers	
Engineering	0.54
Fabrication	2.39
Certification	0.15
Subtotal	3.08
Handling fixtures	
Engineering	0.06
Fabrication	0.47
Certification	0.02
Subtotal	0.55
Shipping fixtures	
Engineering	0.03
Fabrication	0.24
Certification	0.01
Subtotal	0.28
Facilities	
Engineering	0.00
Construction	0.00
Project management	0.00
Subtotal	0.00
Regulatory compliance	1.13
Operations and maintenance	
Materials	6.60
Utilities	0.03
Labor	96.03
Waste Management & Disposal	0.33
Subtotal	102.99
Decontamination & decommissioning	0.00
TOTAL	111.10

Table 4.3 Cost Breakdown (in Millions of Dollars) for Preparation of (29,083) Nonconforming Cylinders for Shipment - Transfer Facility Option

Engineering Development	2.46
Process Equipment	
Engineering	3.70
Fabrications	8.01
Installation	5.24
Certification & Test	0.35
Subtotal	17.30
Process Facilities	
Engineering	16.86
Construction	49.04
Proj. Management	10.97
Subtotal	76.87
Balance of Plant	
Engineering	12.46
Construction	36.26
Proj. Management	8.11
Subtotal	56.83
Regulatory Compliance	56.20
Operations and Maintenance	
Material	82.78
Utilities	28.17
Labor	278.51
Waste Management & Disposal	4.70
Subtotal	394.16
Decont. & Decom.	2.71
TOTAL	604.07

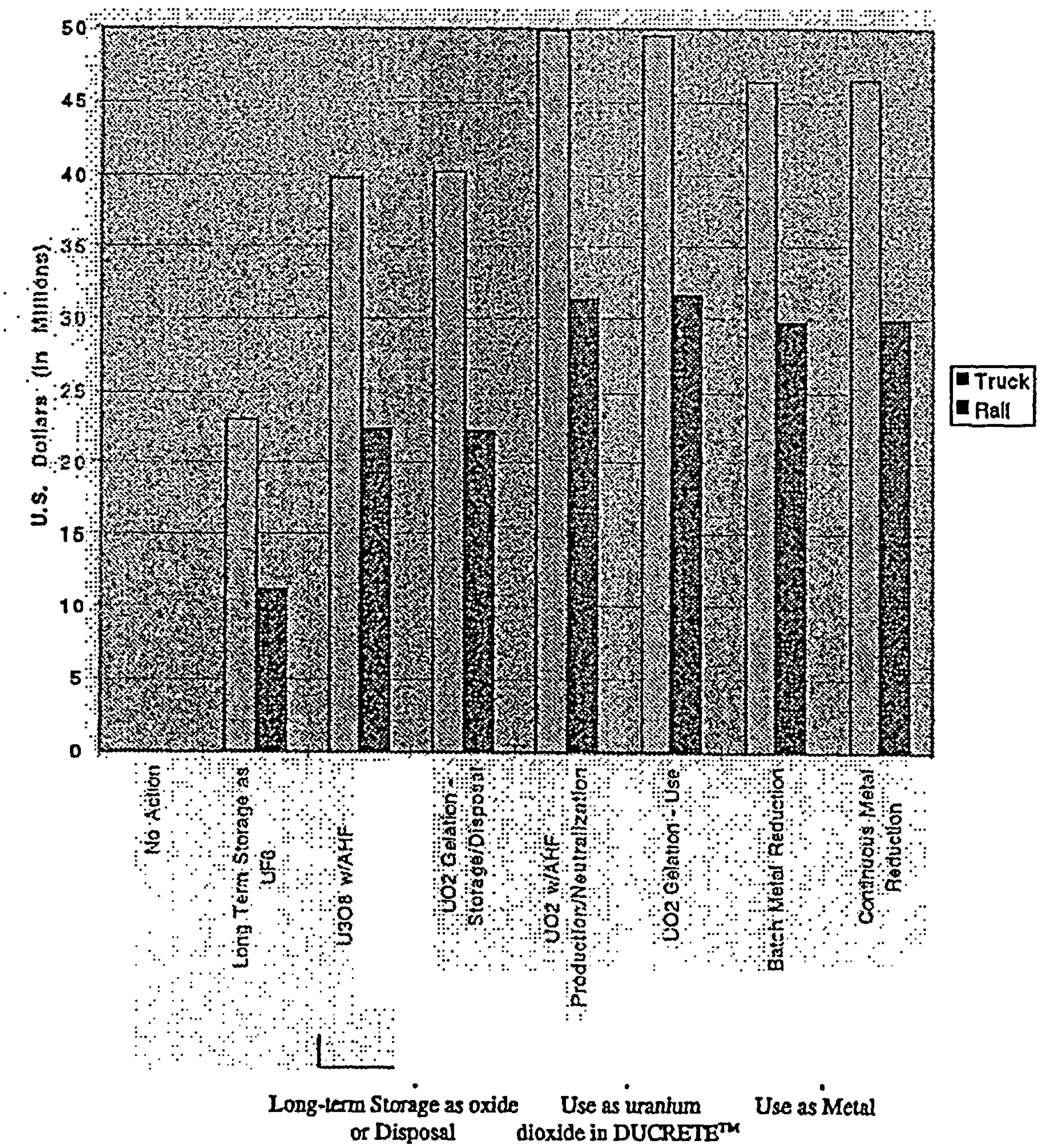
Table 4.4 Cost Breakdown (in Millions of Dollars) for Emptied Cylinder Disposition

	Integration into Oxide Conversion Facility	Integration into Metal Conversion Facility
Technology Development	1.64	1.64
Facility Capital Cost		
Engineering	0.94	1.52
Construction	3.43	5.54
Project management	0.63	1.01
Subtotal	5.00	8.07
O & M		
Labor	0.89	1.24
Utilities	0.09	0.12
Materials	0.04	0.04
Waste Management & Disposal	0.49	0.49
Subtotal	1.51	1.89
D & D	0.11	0.11
TOTAL	8.26	11.71

Table 4.5 Loading, Shipping, and Unloading Cost Breakdown (in Millions of Dollars) by Truck and Rail

	No Action		DUF_6 Long Term Storage		U_3O_8 w/AHF Production/Neutralization *Storage/Disposal*		UO_2 Gelation *Storage/Disposal*		UO_2 w/AHF Production/Neutralization *Storage/Disposal*		UO_2 Gelation *Use*		Batch Metal Reduction *Use*		Continuous Metal Reduction *Use*	
	truck	rail	truck	rail	truck	rail	truck	rail	truck	rail	truck	rail	truck	rail	truck	rail
From Current Site to Conversion Facility	0.00	0.00	-	-	23.25	11.28	23.25	11.28	23.25	11.28	23.25	11.28	23.25	11.28	23.25	11.28
From Conversion Site to Storage/Disposal Site	0.00	0.00	-	-	12.76	8.70	13.14	8.55	-	-	-	-	-	-	-	-
From Conversion Site to DUCRETE™ Container Manufacturer	-	-	-	-	-	-	-	-	13.41	8.24	13.14	8.55	-	-	-	-
From DUCRETE™ Container Manufacturer to SNF Container User	-	-	-	-	-	-	-	-	rail 9.33	9.33	rail 9.33	9.32	-	-	-	-
From Conversion Site to Metal Annulus Manufacturer	-	-	-	-	-	-	-	-	-		-	-	10.43	7.15	10.76	7.30
From Metal Annulus Manufacturer to SNF Container User	-	-	-	-	-	-	-	-	-	-	-	-	rail 8.86	8.86	rail 8.86	8.86
From Conversion Facility to Cylinder Treatment Facility	0.00	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00		0.00
From Cylinder Treatment Facility to DOE Yards (crushed cylinders)	0.00	0.00	-	-	3.87	2.51	3.87	2.51	3.87	2.51	3.87	2.51	3.87	2.51	3.87	2.51
From Current Site to Storage	-	-	23.25	11.28	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	0.00	0.00	23.25	11.28	39.88	22.49	40.26	22.34	49.86	31.36	49.59	31.67	46.41	29.80	46.74	29.95

Figure 4.1 Total Cost by Truck and Rail for the Various Management Strategies



		M	W/AHF Produ			AHF	M		Redu		AHF		
Preparation of Nonconforming Cylinders for Shipment	0.00	111.10	111.10	111.10	111.10	111.10	111.10	111.10	111.10	111.10	111.10	111.10	111.10
Emptied Cylinder Disposition	0.00	0.00	8.26	8.26	8.26	8.26	8.26	8.26	11.72	11.72	8.26	8.26	8.26
Total Loading, Shipping, Unloading for rail	0.00	11.28	22.49	22.49	22.34	31.36	31.36	31.67	29.80	29.95	22.49	22.49	22.34
TOTAL	0.00	171.99	191.46	191.46	191.31	200.33	200.33	200.64	202.23	202.38	191.46	191.46	191.31

Figure 4.2. Total Costs for Transportation Using Overcontainer and Rail

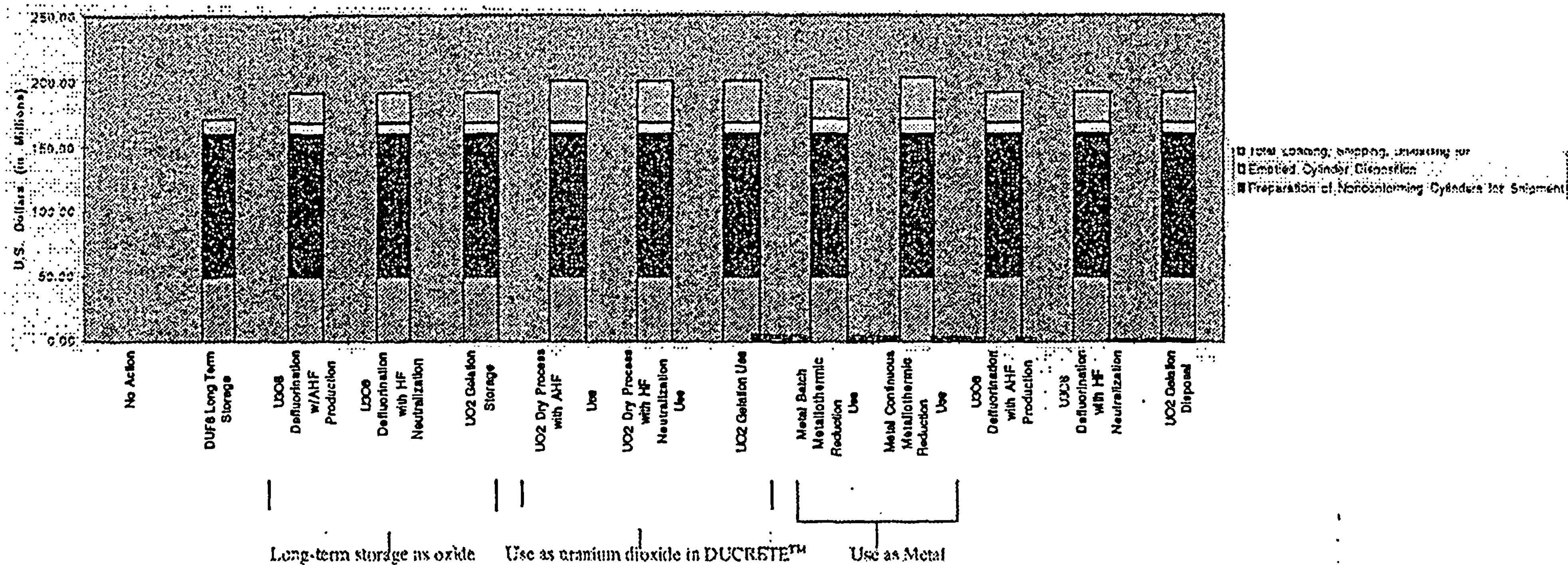
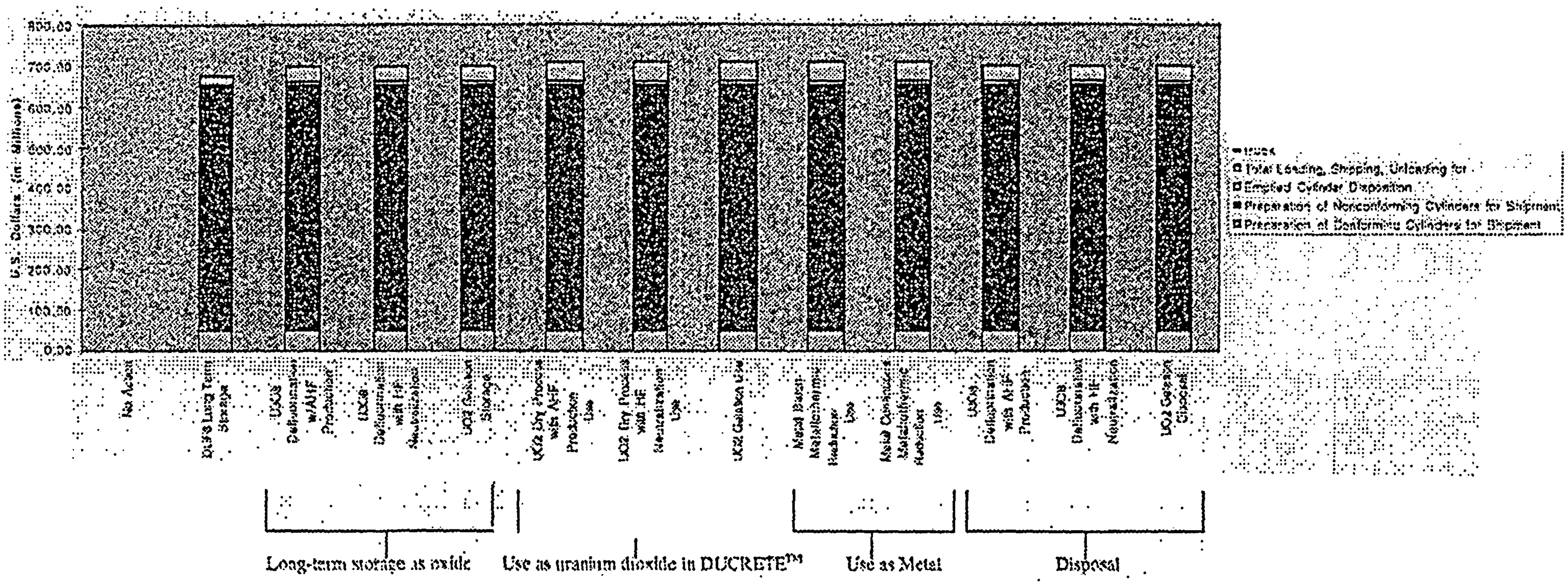


Table 4.7 Cost Breakdown (in Millions of Dollars) for Transportation Using the Transfer Facility Option for the Preparation of (29,083) Nonconforming Cylinders and the Truck Option for the Mode of Transportation

	No Action	DUF_6 Long Term Storage	U_3O_8 Defluorination w/AHF Production *Storage*	U_3O_8 Defluorination with HF Neutralization *Storage*	UO_2 Gelation *Storage*	UO_2 Dry Process with AHF Production *Use*	UO_2 Dry Process with HF Neutralization *Use*	UO_2 Gelation *Use*	Metal Batch Metallothermic Reduction *Use*	Metal Continuous Metallothermic Reduction *Use*	U_3O_8 Defluorination with AHF Production *Disposal*	U_3O_8 Defluorination with HF Neutralization *Disposal*	UO_2 Gelation *Disposal*
Preparation of Conforming Cylinders for Shipment	0.00	49.61	49.61	49.61	49.61	49.61	49.61	49.61	49.61	49.61	49.61	49.61	49.61
Preparation of Nonconforming Cylinders for Shipment	0.00	604.07	604.07	604.07	604.07	604.07	604.07	604.07	604.07	604.07	604.07	604.07	604.07
Emptied Cylinder Disposition	0.00	0.00	8.26	8.26	8.26	8.26	8.26	8.26	11.72	11.72	8.26	8.26	8.26
Total Loading, Shipping, Unloading for Truck	0.00	23.25	39.88	39.88	40.26	49.86	49.86	49.59	46.41	46.74	39.88	39.88	40.26
TOTAL	0.00	676.90	701.79	701.79	702.17	711.77	711.77	711.50	711.78	712.11	701.79	701.79	702.17

Figure 4.3 Total Costs for Transportation Using Transfer Facility and Truck



4.2 Conversion

Conversion of the depleted UF_6 to another chemical form is required for most management strategy alternatives. The following conversion options are considered:

- Conversion to triuranium octaoxide (U_3O_8)
- Conversion to uranium dioxide (UO_2)
- Conversion to metallic uranium

Two different processes for the conversion to U_3O_8, three different processes for the conversion to UO_2, and two different processes for the conversion to metal were analyzed.

4.2.1 Conversion Costs

The costs of the conversion options are summarized in Table 4.8, which reflects costs at CBS Level 6. These costs were evaluated by combining the costs for technology development, process equipment, process facilities, balance of plant, regulatory compliance, operation and maintenance, and decontamination and decommissioning. The process equipment estimate provides costs for the major process equipment, as well as costs for process piping and instrumentation. Costs are based on vendor quotes (where available), historical costs of similar equipment in similar service, current estimating/pricing manuals, or estimated costs of equipment of the same complexity and materials of construction.

Process facilities include costs for buildings and supporting equipment. All major buildings are structural steel frame of standard construction, with the following exceptions:

- The process building is a two-story reinforced concrete structure. Most of this building is "special construction," with "standard construction" support areas, as shown on the layout figures in the *Engineering Analysis Report*. The "special construction" area perimeter walls and ceilings are assumed to be 1-ft thick concrete; interior walls are assumed to be 8-in. thick concrete; and the base mat is assumed to be 2-ft thick concrete. The "standard construction" area walls are assumed to be 8-in. thick concrete; ceilings and elevated floor areas are assumed to be 6-in. thick concrete on metal deck; and the floor slab on grade is assumed to be 8-in. thick concrete.
- The AHF storage building for options producing AHF by-product is a reinforced concrete structure, designed and constructed as "special construction." The walls are assumed to be 8-in. thick concrete; ceilings are assumed to be 6 inches of concrete on metal deck; and the floor slab is assumed to be 2-ft thick concrete.

The operation and maintenance costs include labor, materials, utilities, and waste management and disposal costs necessary to operate the facility at design capacity for 20 years. Conversion to metal produces the salable by-product AHF and waste MgF_2, which is assumed to be disposed as sanitary waste at a cost of $2/cubic foot. Section 6.3.2 discusses the cost impacts if disposal as LLW were required. Conversion to oxide produces either AHF or, when the HF is neutralized, CaF_2. It is noted that neutralization of the HF produced by conversion processes results in higher estimated costs than production and sale of AHF. Section 4.2.2 describes the assumptions regarding the sale of AHF and CaF_2 by-products. Section 6.3.1 describes vulnerabilities associated with sale of these by-products and estimates the cost impacts if disposal were necessary.

Figure 4.4 compares the costs of the various conversion options. With the exception of the gelation process for producing UO_2, conversion costs are lowest for conversion to U_3O_8 and

highest for conversion to uranium metal. Conversion to UO_2 using the dry process is higher than conversion to U_3O_8, while gelation process costs are slightly more than double the dry process costs for conversion to UO_2. Costs for all conversion options are dominated by the operations and maintenance costs. Operations and maintenance costs for the gelation process, particularly materials (which is a factor of almost 4 higher), are more than double the operations and maintenance costs for other options for the conversion to UO_2.

The gelation process produces UO_2 microspheres with a bulk density about 50% higher than the dry conversion processes, which produce pellets. This leads to a reduction in storage and disposal volumetric requirements, and therefore the gelation process minimizes costs for the storage and disposal options involving the oxide. These considerations are further discussed in Section 6.1.4. There are also a number of technical uncertainties with respect to the gelation process, including a practical recovery and recycle process for major process reagents. In the absence of such a process, the effluent stream containing these reagents was assumed to be discarded as a sanitary waste. Recycling these reagents would significantly improve the economics and viability of the gelation process.

The batch metallothermic reduction option for producing metal is estimated to cost significantly more than the continuous metallothermic reduction option. Batch reduction is a mature process with decades of industrial use. The continuous reduction process is still in development. These differences are further discussed in the *Engineering Analysis Report*, Section 3.2.3.

4.2.2 Revenue from Sale of By-product AHF and CaF_2

All of the conversion options produce potentially salable by-products—either AHF or CaF_2. Three of the oxide conversion options and both of the metal conversions options produce AHF. Defluorination with AHF production is superior to defluorination with HF neutralization in terms of by-product value and waste avoidance. In the unlikely event that the recovered AHF (because of the small [< 1 ppm] uranium concentration) could not be sold for unrestricted use or the even more unlikely event that it could not be recycled in the nuclear fuel industry, the concentrated HF would be neutralized with lime (CaO) to form CaF_2. Neutralization of HF may also be undertaken to avoid storage and transportation of large quantities of hazardous AHF. Neutralization would further reduce the already small concentration of uranium in the by-product. In the absence of regulatory constraints regarding the uranium content, the CaF_2 could be sold as a feedstock (i.e., a high-quality fluorspar substitute) for the commercial production of AHF. The by-product value of CaF_2 is significantly less than AHF and major quantities of lime would be required for neutralization, adding to the cost of input reagents.

The largest use of AHF is in the manufacture of fluorocarbons. The fluorocarbon market accounts for about 65-70% of AHF demand and is thus the primary driving force in hydrogen fluoride demand. Forecasting fluorocarbon demand is still a very uncertain exercise. Although the replacement fluorocarbons use more hydrogen fluoride per unit than the chlorinated fluorocarbons, representatives of the major North American fluorocarbon producers are divided in forecasting demand. It should be noted that the annual production of by-product AHF from an oxide conversion facility (28,000 MT/yr. UF_6) is about 9,200 MT. This is approximately 5% or less of the estimated U.S. annual capacity for HF production.

In addition to the uncertain market, there is concern about possible public reaction to uranium contaminants. If the fluorine chemical is to be sold in North America, it may be subjected to higher purity standards due to the source material. Allied Signal has proposed to overcome this potential problem by using the AHF in nuclear reactor fuel production. The aqueous HF produced by Cogema in France as part of their defluorination process is viewed by potential European purchasers outside the nuclear fuel cycle as very pure and highly desirable. It is marketed to outside buyers in the glass and steel industries. The uranium content of this high purity HF is

below the 0.1 ppm uranium instrument detection levels, well within the 5 ppm specification for aqueous HF sales in Europe.

The major potential buyers for AHF negotiate prices. The price published in the *Chemical Market Reporter* (formerly *Chemical Marketing Reporter*) (CMR) of $1.5125/kg was used in this analysis, although the actual price would be negotiated at the time of sale. Prices in the CMR were checked between June 30, 1995, and March 29, 1996, and there was no change. It should be noted that chemical prices quoted in the CMR come with a disclaimer to the effect that they are based on price information obtained from suppliers and do not necessarily represent levels at which transactions actually may have occurred.

Calcium fluoride is a potential major feed stock for HF production as a substitute for mined fluorspar. If a market could be found, possible fluorspar prices are $97.66/ton ($.10736/kg) (U.S. Department of Interior). In the previous three years, fluorspar prices had declined slightly and steadily to the current level. This is partly due to an increase in Chinese fluorspar and increased U.S. government licensing for fluorspar mining.

Table 4.9 shows the annual revenue from sale of AHF and CaF_2 by-products produced from conversion of depleted UF_6 to other uranium forms. The prices quoted above were used to calculate these revenues. The discounted values (7% p.a.) of the revenue stream over the 20-year conversion campaign are shown in Table 4.8.

Table 4.8 Cost Breakdown (in Millions of Dollars) for Conversion Options

	U_3O_8		UO_2			Metal	
	With AHF Production	With HF Neutralization	With AHF Production	With HF Neutralization	Gelation	Batch Metallothermic Reduction	Continuous Metallothermic Reduction
Tech. Development	9.84	5.74	13.94	9.84	24.60	4.92	20.50
Process Equipment							
Engineering	4.74	4.43	7.74	7.13	21.98	7.80	6.52
Fabrication	11.91	10.93	18.96	17.41	51.81	17.98	15.22
Installation	5.19	5.04	8.91	8.27	27.18	10.03	8.20
Certification & Test	0.52	0.48	0.83	0.76	2.26	0.79	0.66
Subtotal	22.36	20.88	36.44	33.57	103.23	36.60	30.60
Process Facilities							
Engineering	10.16	9.98	14.91	13.58	23.89	18.27	16.09
Construction	29.56	29.05	43.39	39.50	69.51	53.14	46.82
Proj. Management	6.61	6.50	9.71	8.84	15.55	11.89	10.47
Subtotal	46.33	45.53	68.01	61.92	108.95	83.30	73.38
Balance of Plant							
Engineering	6.40	6.63	7.76	7.66	13.08	8.33	8.22
Construction	18.63	19.30	22.57	22.29	38.04	24.22	23.91
Proj. Management	4.17	4.32	4.12	4.99	8.51	5.42	5.35
Subtotal	29.20	30.25	34.45	34.94	59.63	37.97	37.48
Regulatory Compliance	22.70	22.70	22.70	22.70	22.70	22.70	22.70
Operations and Maintenance							
Material	52.71	55.96	66.12	66.45	261.94	189.74	171.76
Utilities	12.83	13.10	14.55	14.82	46.05	23.84	13.30
Labor	134.68	137.44	152.72	155.48	242.11	250.19	139.57
Waste Management & Disposal	11.86	2.92	12.47	3.47	24.45	39.14	6.14
By-product Revenue	-77.32	-11.02	-77.31	-11.02	-77.32	-26.11	-26.11
Subtotal	134.76	198.40	168.55	229.20	497.23	476.80	304.66
Decont. & Decom.	1.76	1.73	2.51	2.34	4.87	2.83	2.54
TOTAL	266.95	325.23	346.60	394.51	821.21	665.12	491.86

Figure 4.4 Total Costs for Different Conversion Options

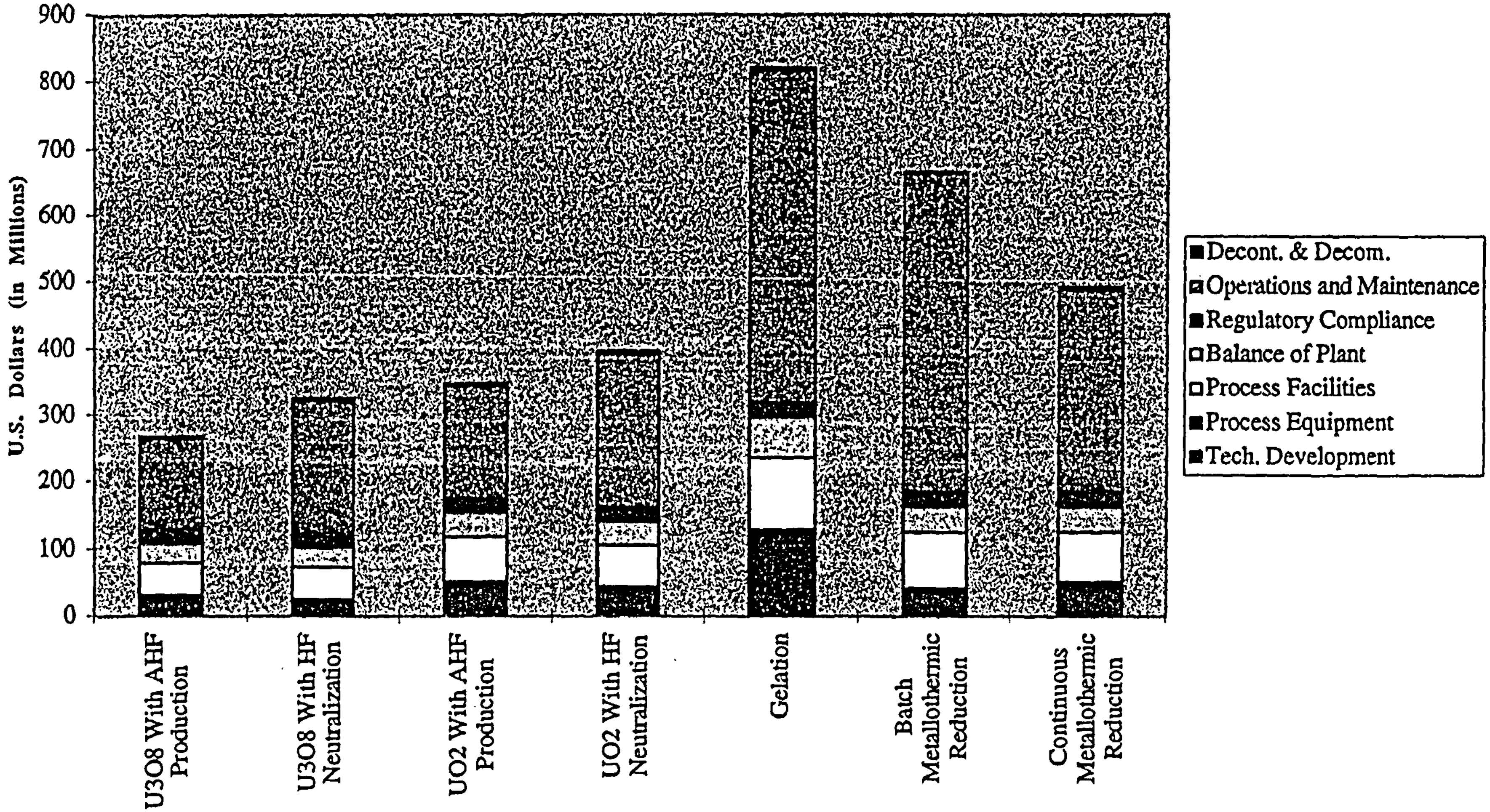


Table 4.9 Annual Revenue from Sale of AHF and CaF_2 By-products from Conversion Options in Millions of Dollars

Option	Quantity (MT)	Reference Case
U_3O_8 w/AHF Production	9,237 AHF 419 CaF_2	Revenue from AHF: 13.97 Revenue from CaF_2: 0.045
U_3O_8 w/HF Neutralization	CaF_2 18,600	Revenue from CaF_2: 1.99
UO_2 w/AHF	9,237 AHF 421 CaF_2	Revenue from AHF: 13.97 Revenue from CaF_2: 0.045
UO_2 w/HF Neutralization	CaF_2 18,600	Revenue from CaF_2: 1.99
UO_2 Gelation	9,237 AHF 421 CaF_2	Revenue from AHF: 13.97 Revenue from CaF_2: 0.045
Batch metallothermic reduction to uranium metal	3,121 AHF 118 CaF_2	Revenue from AHF: 4.72 Revenue from CaF_2: 0.013
Continuous metallothermic reduction to uranium metal	3,121 AHF 118 CaF_2	Revenue from AHF: 4.72 Revenue from CaF_2: 0.013

4.3 Manufacture and Use

There is a potential use for depleted uranium in radiation shielding applications, specifically for storage, transportation, or disposal containers for spent nuclear fuel (SNF). Two manufacturing options were considered: oxide shielding (DUCRETE™) and uranium metal shielding. In the oxide shielding application, dense UO_2 would be substituted as the aggregate in standard concrete for the construction of containers for the dry storage of SNF. In the metal shielding application, molten depleted uranium metal would be cast into a component of a multipurpose unit suitable for the storage, transportation, and disposal of SNF.

The total shielding cost was evaluated by combining the costs of engineering development, manufacturing equipment, manufacturing facilities, balance of plant, regulatory compliance, operations and maintenance, and decontamination and decommissioning. The cost of the depleted uranium is excluded from this estimate because the cost of converting depleted UF_6 to depleted uranium metal or dense UO_2 is captured in the conversion options and is part of any use alternative. The operations and maintenance costs include the labor, materials, utilities, and waste management and disposal costs necessary to operate the facility at design capacity for 20 years.

No credit has been taken in the reference case for either the metal or the DUCRETE™ casks. Use of the DUCRETE™ casks for dry storage of spent nuclear fuel would avoid the cost of the standard vertical concrete containers currently available. Similarly, use of metal casks would avoid the cost of other options. In addition, these applications could delay costs associated with disposal of depleted uranium. If the depleted uranium casks are also used for the disposal of the spent nuclear fuel, future depleted uranium disposal costs could be avoided altogether. Cases which consider a cask credit are found in Section 6.1.3.

The manufacturing equipment estimate provides costs for the major process equipment, including process piping and instrumentation. Costs are based on vendor quotes (where available), historical costs of similar equipment in similar service, current estimating/pricing manuals, or estimated costs of equipment of the same complexity and materials of construction.

Manufacturing facilities include costs for buildings and supporting equipment. The main processing buildings for the two applications differ due to the types of shielding materials produced and the forming operations required. The main processing building for the metal shielding application is a reinforced

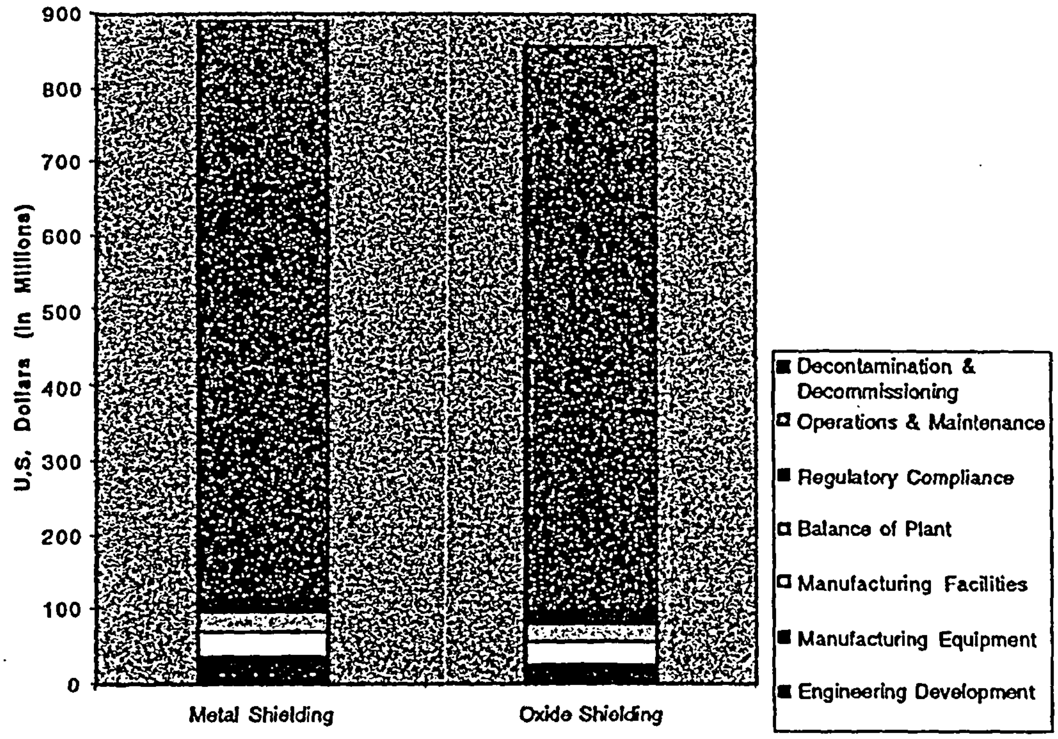
concrete, high-bay structure, while the main processing building for the oxide shielding application is based upon standard construction concrete block and spread footers.

The costs for oxide and metal shielding are summarized in Table 4.10 and compared in Figure 4.5. The estimated costs for the metal and oxide shielding applications are similar. The majority of the costs for both options are operations and maintenance costs. For metal shielding, operations and maintenance costs account for 87% of total shielding cost. For oxide shielding, they account for 89% of total shielding cost.

Table 4.10 Cost Breakdown (in Millions of Dollars) for Manufacture of Metal and Oxide Shielding Options

	Metal Shielding	Oxide Shielding
Engineering Development	16.40	6.56
Manufacturing Equipment		
Engineering	4.11	3.94
Fabrication	11.55	11.06
Installation	3.19	3.06
Certification and Test	0.51	0.49
Subtotal	19.36	18.55
Manufacturing Facilities		
Engineering	7.64	6.87
Construction	22.26	20.02
Project Management	4.99	4.49
Subtotal	34.89	31.38
Balance of Plant		
Engineering	5.95	4.94
Construction	17.31	14.36
Project Management	3.88	3.22
Subtotal	27.14	22.52
Regulatory Compliance	17.43	17.43
Operations & Maintenance		
Materials	311.49	296.05
Utilities	42.30	42.41
Labor	415.13	416.18
Waste Management	3.70	3.92
Cask Credit	0.00	0.00
Subtotal	772.62	758.56
Decontamination & Decommissioning	1.46	1.30
TOTAL	889.30	856.30

Figure 4.5 Total Costs of Manufacture of Metal and Oxide Shielding Options



4.4 Long-term Storage

Storage of depleted uranium is predicated on its use at some later date. In the engineering analysis, storage options are defined by the type of storage facility, and suboptions are defined by the chemical form in which the depleted uranium is stored. The types of storage facilities analyzed are (1) buildings, (2) below ground vaults, and (3) a mined cavity. The three chemical forms analyzed are (1) UF_6, (2) U_3O_8, and (3) UO_2, with corresponding assumed bulk densities of 4.6 gram per cubic centimeter (g/cc), 3.0 g/cc, and 9.0 g/cc at ambient temperature.[3] The area required to store depleted uranium depends on the uranium content in the storage form, the bulk density of the compound stored, the type of storage containers used, and the configuration of the storage containers. UF_6 would be stored in Type 48 cylinders, while U_3O_8 and UO_2 would be stored in 55- and 30-gallon drums, respectively. Total storage area requirements are greatest for U_3O_8 and least for UO_2, based on the preconceptual designs in the *Engineering Analysis Report.*

The storage cost was evaluated by combining the costs of technology development, equipment, facilities, balance of plant, regulatory compliance, and operations and maintenance. Facility costs include costs for the storage facilities (i.e., buildings, vaults, or a mined cavity), the receiving warehouse and repackaging building, and the cylinder washing building for the UF_6 storage options. Balance of plant costs include site improvements and utilities, the site support buildings such as the administration building and the workshop, and mobile yard equipment. Costs for site improvements and utilities are based on preliminary estimates for site clearing, grubbing, and mass earthwork, as well as other information provided in the *Engineering Analysis Report.* Operations and maintenance costs are based on emplacement over 20 years followed by surveillance and monitoring until 2040. Surveillance and monitoring will likely continue beyond 2040, but this is the period assumed for purposes of analysis.

There is considerable variation and uncertainty in costs associated with excavation and maintenance for the mined cavity. Available data from the Yucca Mountain and Waste Isolation Pilot Plant (WIPP) projects were used for estimating these costs.

Table 4.11 provides a summary of the costs of the various long-term storage options considered. It is evident from Table 4.11 that the lowest-cost storage option for UF_6, U_3O_8, and UO_2 is above ground (buildings), while the highest-cost storage option is a mined cavity. Significantly greater operations and maintenance (materials) and facility costs are estimated for the mined cavity than for the building or vault options. Storage in the oxide forms differs from storage as depleted UF_6 in six key areas:

- Lesser weight rating of the depleted uranium handling equipment due to the lower storage container weight (the weight rating is higher for UO_2 than for U_3O_8)
- Different equipment used for cylinder repackaging than for drum repackaging (e.g., autoclaves versus hoppers and vibrating platforms)
- Greater number of storage buildings required for storing U_3O_8, fewer for storing UO_2
- Larger site required for storing U_3O_8, smaller for storing UO_2
- Absence of a cylinder cleaning building
- Higher material and staffing requirements for storing U_3O_8, lower for storing UO_2

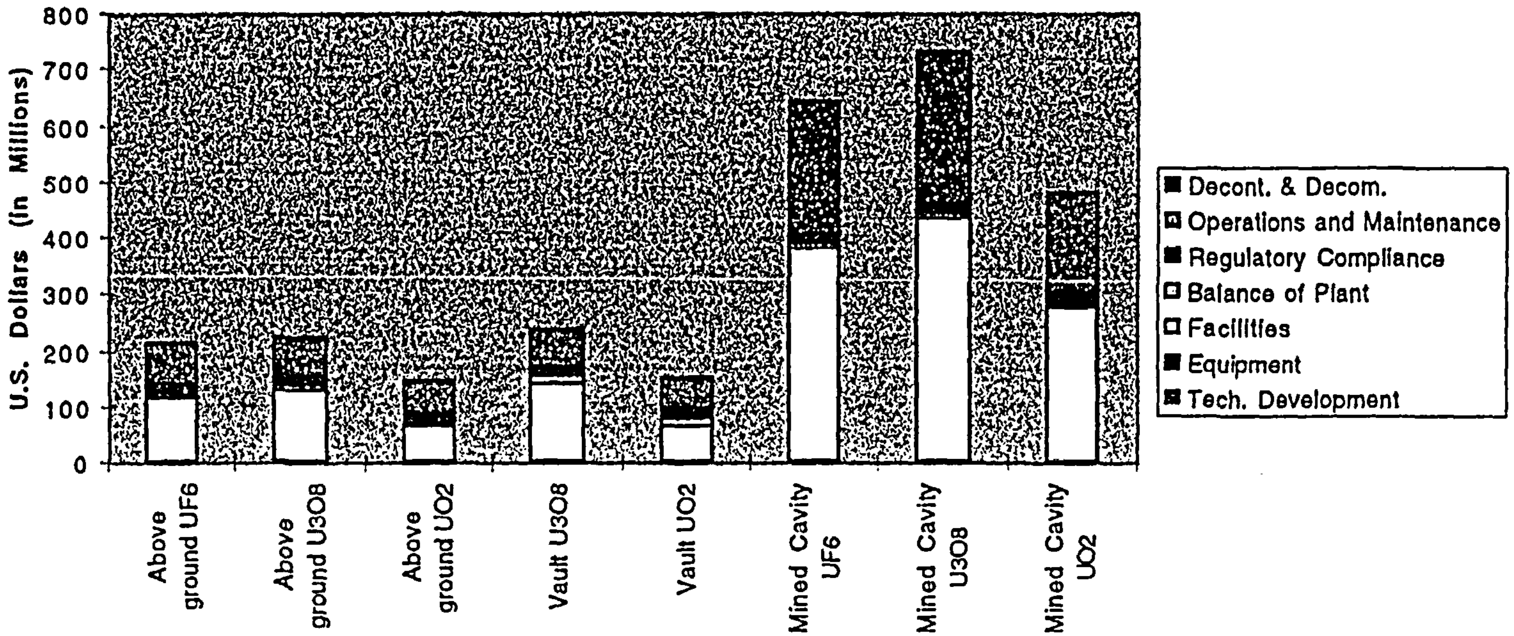
[3] The density of depleted UF_6 decreases dramatically when it is heated to a maximum working cylinder temperature of 250°F. Cylinders are filled so that they are about 62% full at ambient temperature.

Figure 4.6 compares the long-term storage costs for all options considered. For above ground storage (buildings), the facilities cost accounts for 52%, 57%, and 43% of the total storage cost for UF_6, U_3O_8, and UO_2, respectively, while the operations and maintenance cost accounts for 32%, 29%, and 37% of the total storage cost. For the mined cavity option, the facilities cost accounts for 58%, 59%, and 57% of the total storage cost for UF_6, U_3O_8, and UO_2, respectively, while the operations and maintenance cost accounts for 36%, 36%, and 37% of the total storage cost. In all cases, facilities costs are dominant, making up nearly half of total costs.

Table 4.11 Cost Breakdown (in Millions of Dollars) for Long-term Storage Options

	Aboveground (Buildings)			Vault		Mined Cavity		
	UF_6	U_3O_8	UO_2	U_3O_8	UO_2	UF_6	U_3O_8	UO_2
Tech. Development	0.82	0.82	0.82	1.64	1.64	3.28	3.28	3.28
Equipment								
Engineering	0.95	0.42	0.38	0.24	0.23	0.47	0.30	0.30
Fabrication	1.39	1.01	0.94	0.68	0.65	1.33	0.93	0.90
Installation	2.68	0.79	0.71	0.36	0.34	0.68	0.36	0.38
Certification & Test	0.07	0.05	0.05	0.03	0.03	0.07	0.05	0.04
Subtotal	5.09	2.27	2.08	1.31	1.25	2.55	1.64	1.62
Facilities								
Engineering	21.30	24.30	11.91	26.17	12.59	71.18	81.50	51.77
Construction	77.45	88.37	43.32	95.17	45.79	258.82	296.38	188.27
Proj. Management	14.13	16.13	7.91	17.37	8.36	47.24	54.09	34.36
Subtotal	112.88	128.80	63.14	138.71	66.74	377.24	431.97	274.40
Balance of Plant								
Engineering	1.58	1.62	1.34	2.72	1.93	1.20	1.43	1.13
Construction	5.74	5.91	4.88	9.89	7.01	4.37	5.21	4.12
Proj. Management	1.05	1.08	0.89	1.80	1.28	0.80	0.95	0.75
Subtotal	8.37	8.61	7.11	14.41	10.22	6.37	7.59	6.00
Regulatory Compliance	18.61	18.61	18.61	18.61	18.61	18.61	18.61	18.61
Operations and Maintenance								
Material	19.41	12.37	8.05	10.38	6.46	185.26	211.38	128.53
Utilities	2.12	2.41	1.63	1.98	1.36	1.78	1.99	1.47
Labor	47.03	50.83	45.02	49.80	45.97	49.08	54.48	48.90
Waste Management & Disposal	0.15	0.27	0.13	0.27	0.13	0.08	0.27	0.13
Subtotal	68.71	65.88	54.83	62.43	53.92	236.20	268.12	179.03
Decont. & Decom.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	214.48	224.99	146.59	237.11	152.38	644.25	731.21	482.94

Figure 4.6 Total Costs for Long-term Storage Options



4.5 Disposal

Disposal options and suboptions are defined by the type of disposal facility and the nature of the waste form. The engineering analysis considered three disposal facility options: (1) engineered trench, (2) below ground vault, and (3) mined cavity. Each option was evaluated for the same four waste form suboptions: (1) grouted (cemented) U_3O_8, (2) grouted UO_2, (3) bulk (i.e., not grouted) U_3O_8, and (4) bulk UO_2. The area required to dispose of the depleted uranium depends on the uranium content in the disposal form, the bulk density of the compound stored, the type of storage containers used, and the configuration of the storage containers. Both grouted and bulk U_3O_8 would be disposed of in 55-gallon drums; grouted and bulk UO_2 would be disposed of in 30-gallon drums. The following list ranks the four waste forms from least to greatest number of disposal containers and disposal area required: (1) bulk UO_2, (2) grouted UO_2, (3) bulk U_3O_8, and (4) grouted U_3O_8.

The disposal cost was evaluated by combining the costs of technology development, equipment, facilities, balance of plant, regulatory compliance, operations and maintenance, and decontamination and decommissioning. Facility costs include costs for the disposal facilities (i.e., trenches, vaults, or mined cavity) and waste form preparation facilities (i.e., the cementing building and the curing building for grouted waste form preparation). Balance of plant costs include site improvements and utilities and the site support buildings such as the administration building, the product receiving warehouse, and the supply and shipping warehouse. Costs for site improvements and utilities are based on preliminary estimates for site clearing, grubbing, and mass earthwork, as well as other information provided in the *Engineering Analysis Report*. Operations and maintenance costs include the labor, utilities, materials, and waste management costs necessary to operate the waste form facility for 20 years. Emplacement and closure and surveillance and maintenance costs are incurred over the same 20-year period. All operations of the waste form and disposal facilities would be completed in 2029.

As with the option for storage in a mined cavity, there is considerable variation and uncertainty in costs associated with excavation and maintenance for disposal in a mined cavity. Available data from the Yucca Mountain and WIPP projects were used for estimating these costs.

Disposal costs for bulk oxides vary from storage costs for the same oxides in vaults or a mined cavity due to the differences listed below. Most of these differences are the result of providing accessibility in order to allow the surveillance and maintenance necessary for storage options.

- A waste form preparation facility is needed for disposal options, but not for storage options.
- Disposal vaults are covered with concrete and earth, while storage vaults are not.
- Disposal vaults are smaller and contain interior concrete walls.
- Disposal drifts are shorter, narrower, and shallower than storage drifts because access for inspections after emplacement is unnecessary. Access to drifts is by shafts for storage facilities and by ramp for disposal facilities.
- Drums are packed more tightly into disposal facilities than in storage facilities.
- Disposal facilities are not monitored for 20 years after emplacement as storage facilities are.
- Regulatory compliance costs for disposal options are more than double the regulatory compliance costs for the long-term storage options.

Table 4.12 provides a summary of the costs of the various disposal options considered. Waste form preparation costs are given first, followed by disposal facility costs and total costs. It is evident from Table 4.12 that the lowest-cost disposal option is disposal as bulk UO_2 in an engineered trench, while the highest-cost disposal option is disposal as grouted U_3O_8 in a mined cavity. Mined cavity disposal may be desirable, however, due to environmental impact considerations since this option provides the greatest isolation of the waste form. Additional discussion may be found in Section 6.13 of the *Engineering Analysis Report.*

Figure 4.7 compares the disposal costs for all options considered. It is noted that disposal costs (exclusive of waste form preparation costs) vary directly with the number of disposal containers and the disposal area required for each waste form and are, from least to greatest within each facility type: (1) bulk UO_2, (2) grouted UO_2, (3) bulk U_3O_8, and (4) grouted U_3O_8. When the preparation costs are added, the order shifts and disposal of bulk U_3O_8 has a lower cost than disposal of grouted UO_2 because the waste form preparation costs associated with the bulk U_3O_8 are about one-third of those associated with grouted UO_2.

For a given waste form (e.g., bulk U_3O_8 or grouted UO_2), preparation costs are constant, regardless of the type of disposal facility (e.g., engineered trench), except for the technology development cost. For a given type of disposal facility, waste form preparation costs vary in the same manner as disposal facility costs, with bulk UO_2 having the least cost and grouted U_3O_8 having the greatest cost. Preparation costs are higher than other cost elements for all trench disposal options, making up about one-half the total costs for bulk disposal forms and three-fourths the total cost for grouted waste forms. Facility costs dominate total costs for the more complex waste disposal facilities.

For purposes of this analysis, regulatory compliance costs were assumed to be constant, regardless of facility or waste form. Accordingly, regulatory compliance is a significant factor at the lower end of the spectrum, making up 34% of total disposal costs for bulk UO_2 in an engineered trench. Compliance costs make up only about 3% of total costs for the highest-cost option, grouted U_3O_8 in a mined cavity.

Table 4.12 Cost Breakdown (in Millions of Dollars) for Disposal Options

Preparation	U_3O_8 Bulk			U_3O_8 Grouted			UO_2 Bulk			UO_2 Grouted		
	Engineered Trench	Vault	Mined Cavity	Engineered Trench	Vault	Mined Cavity	Engineered Trench	Vault	Mined Cavity	Engineered Trench	Vault	Mined Cavity
Technology Development	6.56	6.56	8.20	8.20	8.20	9.84	6.56	6.56	8.20	8.20	8.20	9.84
Process Equipment												
Engineering	0.00	0.00	0.00	5.61	5.61	5.61	0.00	0.00	0.00	4.32	4.32	4.32
Fabrication	0.00	0.00	0.00	16.78	16.78	16.78	0.00	0.00	0.00	12.98	12.98	12.98
Installation	0.00	0.00	0.00	4.65	4.65	4.65	0.00	0.00	0.00	3.53	3.53	3.53
Certification and Test	0.00	0.00	0.00	0.60	0.60	0.60	0.00	0.00	0.00	0.46	0.46	0.46
Subtotal	0.00	0.00	0.00	27.64	27.64	27.64	0.00	0.00	0.00	21.29	21.29	21.29
Process Facilities												
Engineering	0.00	0.00	0.00	6.27	6.27	6.27	0.00	0.00	0.00	3.71	3.71	3.71
Construction	0.00	0.00	0.00	17.39	17.39	17.39	0.00	0.00	0.00	10.28	10.28	10.28
Project Management	0.00	0.00	0.00	4.01	4.01	4.01	0.00	0.00	0.00	2.37	2.37	2.37
Subtotal	0.00	0.00	0.00	27.67	27.67	27.67	0.00	0.00	0.00	16.36	16.36	16.36
Balance of Plant												
Engineering	6.01	6.01	6.01	10.90	10.90	10.90	3.63	3.63	3.63	7.68	7.68	7.68
Construction	16.56	16.56	16.56	30.05	30.05	30.05	9.99	9.99	9.99	21.17	21.17	21.17
Project Management	3.86	3.86	3.86	7.00	7.00	7.00	2.33	2.33	2.33	4.93	4.93	4.93
Subtotal	26.43	26.43	26.43	47.95	47.95	47.95	15.95	15.95	15.95	33.78	33.78	33.78
Regulatory Compliance	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
Operation & Maintenance												
Materials	0.14	0.14	0.14	122.86	122.86	122.86	0.08	0.08	0.08	13.26	13.26	13.26
Utilities & Consumables	3.51	3.51	3.51	6.04	6.04	6.04	1.95	1.95	1.95	3.32	3.32	3.32
Labor	28.41	28.41	28.41	75.60	75.60	75.60	28.36	28.36	28.36	70.87	70.87	70.87
Waste Management	1.17	1.17	1.17	1.98	1.98	1.98	0.72	0.72	0.72	1.19	1.19	1.19
Subtotal	33.23	33.23	33.23	206.48	206.48	206.48	31.11	31.11	31.11	88.64	88.64	88.64
Decont. & Decom.	0.60	0.60	0.60	1.83	1.83	1.83	0.38	0.38	0.38	1.26	1.26	1.26
Total Preparation Cost	68.84	68.84	70.48	321.79	321.79	323.43	56.02	56.02	57.66	171.55	171.55	173.19

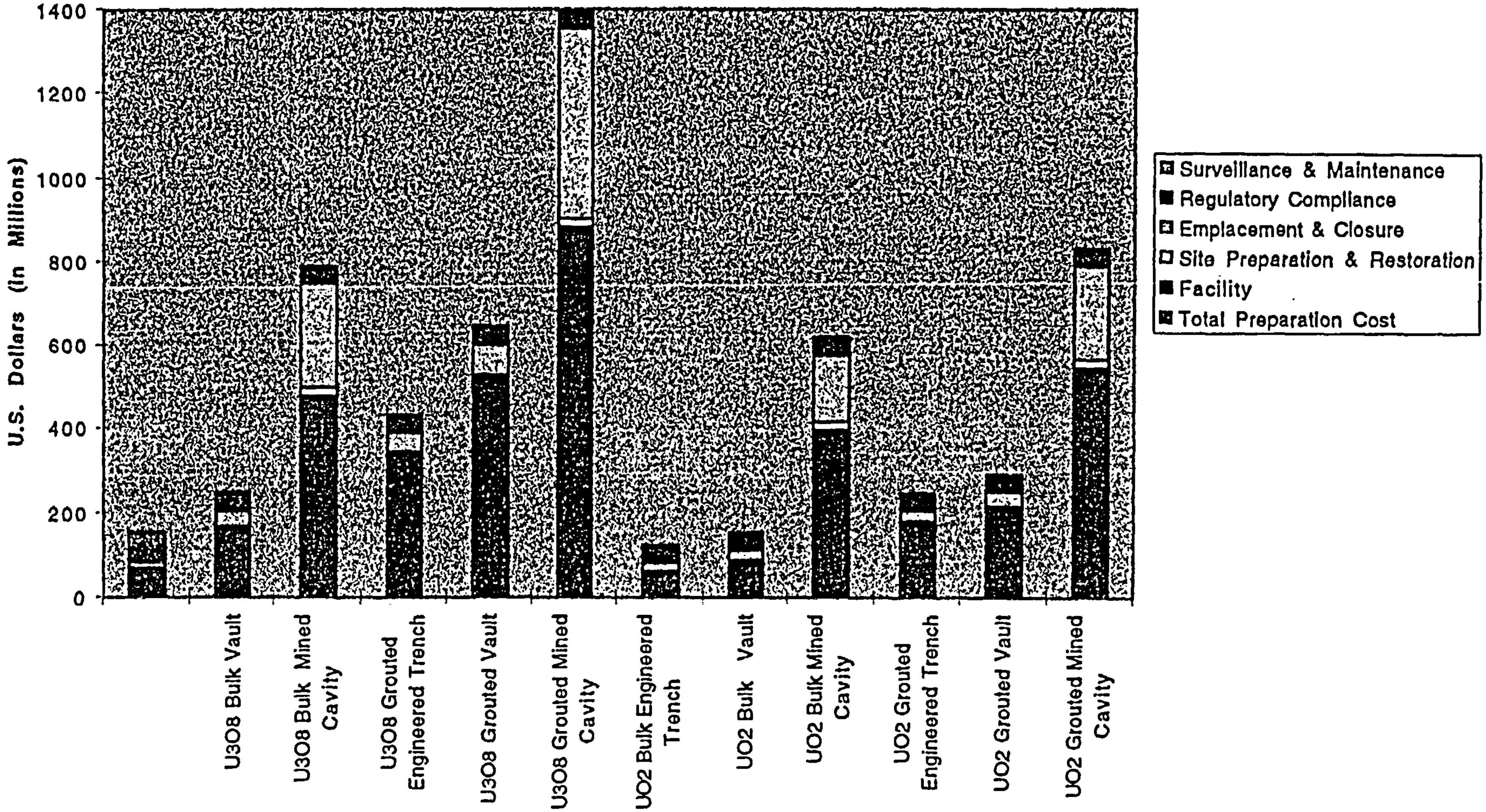
[Table 4.12 is continued on the next page]

Table 4.12 Cost Breakdown (in Millions of Dollars) for Disposal Options (Continued)

	U_3O_8 Bulk			U_3O_8 Grouted			UO_2 Bulk			UO_2 Grouted		
	Engineered Trench	Vault	Mined Cavity	Engineered Trench	Vault	Mined Cavity	Engineered Trench	Vault	Mined Cavity	Engineered Trench	Vault	Mined Cavity
Facility												
Engineering	3.73	29.33	87.05	7.12	61.85	119.05	1.86	8.42	72.16	2.50	12.81	79.56
Construction	7.20	56.62	271.44	13.73	119.41	371.21	3.59	16.25	225.01	4.82	24.73	248.07
Project Management	1.29	10.13	50.53	2.46	21.37	69.11	0.64	2.91	41.89	0.86	4.43	46.18
Subtotal	12.22	96.08	409.02	23.31	202.63	559.37	6.09	27.58	339.06	8.18	41.97	373.81
Site Prep & Restoration												
Engineering	0.17	0.32	3.62	0.27	0.55	3.78	0.11	0.14	3.55	0.13	0.17	3.59
Construction	0.61	1.15	13.18	0.97	1.99	13.75	0.40	0.49	12.91	0.47	0.63	13.05
Project Management	0.11	0.21	2.41	0.18	0.36	2.51	0.07	0.09	2.36	0.09	0.12	2.38
Subtotal	0.89	1.68	19.21	1.42	2.90	20.04	0.58	0.72	18.82	0.69	0.92	19.02
Emplacement & Closure												
Materials	1.40	2.15	28.49	2.45	3.17	47.31	0.85	0.79	24.76	1.05	1.50	35.06
Equipment	3.63	3.84	183.46	5.16	5.24	357.60	2.33	2.23	103.23	2.44	2.76	143.39
Labor	25.58	33.21	36.93	35.82	66.26	44.80	14.43	23.71	33.30	18.55	30.06	43.28
Subtotal	30.61	39.20	248.88	43.43	74.67	449.71	17.61	26.73	161.29	22.04	34.32	221.73
Regulatory Compliance	40.35	40.35	40.35	40.35	40.35	40.35	40.35	40.35	40.35	40.35	40.35	40.35
Surveillance & Maintenance												
Materials	0.79	1.36	0.58	1.03	2.76	0.75	0.67	0.44	0.42	0.71	0.63	0.58
Labor	1.50	1.50	1.63	1.50	1.50	1.63	1.50	1.50	1.63	1.50	1.50	1.63
Subtotal	2.29	2.86	2.21	2.53	4.26	2.38	2.17	1.94	2.05	2.21	2.13	2.21
Total Facility Cost	86.36	180.17	719.67	111.04	324.81	1,071.85	66.80	97.32	561.57	73.47	119.69	657.12

	U_3O_8 Bulk			U_3O_8 Grouted			UO_2 Bulk			UO_2 Grouted		
	Engineered Trench	Vault	Mined Cavity	Engineered Trench	Vault	Mined Cavity	Engineered Trench	Vault	Mined Cavity	Engineered Trench	Vault	Mined Cavity
GRAND TOTAL	155.20	249.01	790.15	432.83	646.60	1,395.28	122.82	153.34	619.23	245.02	291.24	830.31

Figure 4.7 Total Costs for Disposal Options



4.6 Continued Storage at Current Sites

Storage of depleted UF_6 in the current cylinders and yards would continue for several years under all alternatives. For all alternatives except the No Action alternative, storage as depleted UF_6 in the current yards would continue from 1999 to 2029, with the amount of depleted UF_6 in storage decreasing by 5% per year beginning in 2009 until it is gone by 2029. Under the No Action alternative, storage as depleted UF_6 in the current yards would continue from 1999 to 2040, without reduction of the amount of depleted UF_6 in storage.

The continued storage cost was evaluated by combining the costs of equipment, cylinder placement, facilities, and surveillance and maintenance. Equipment costs include the costs of capital equipment required to store the depleted UF_6 cylinders in yards. Cylinder placement costs include estimates of the cost of stacking and restacking cylinders in the storage yards, including the newly constructed or modified yards. Facilities costs include estimates for constructing new storage yards at the three existing facilities. Cylinder placement and facilities costs occur in the first six years and are therefore identical for the action and No Action alternatives.

Surveillance and maintenance costs include repainting, management of substandard cylinders (including breach repair and transfer of contents), general cylinder maintenance (including valve/plug replacement and paint touch-up), general yard and equipment maintenance, cylinder inspections, data tracking, systems planning and execution, conduct of operations, and engineering development. These costs decline for the action alternatives until they are zero by the year 2029 when all the cylinders are gone. Surveillance and maintenance costs continue at a steady rate for the entire time period under the No Action alternative and are therefore higher. There are no decontamination and decommissioning costs for the No Action alternative because storage of the depleted UF_6 cylinders is assumed to continue indefinitely.

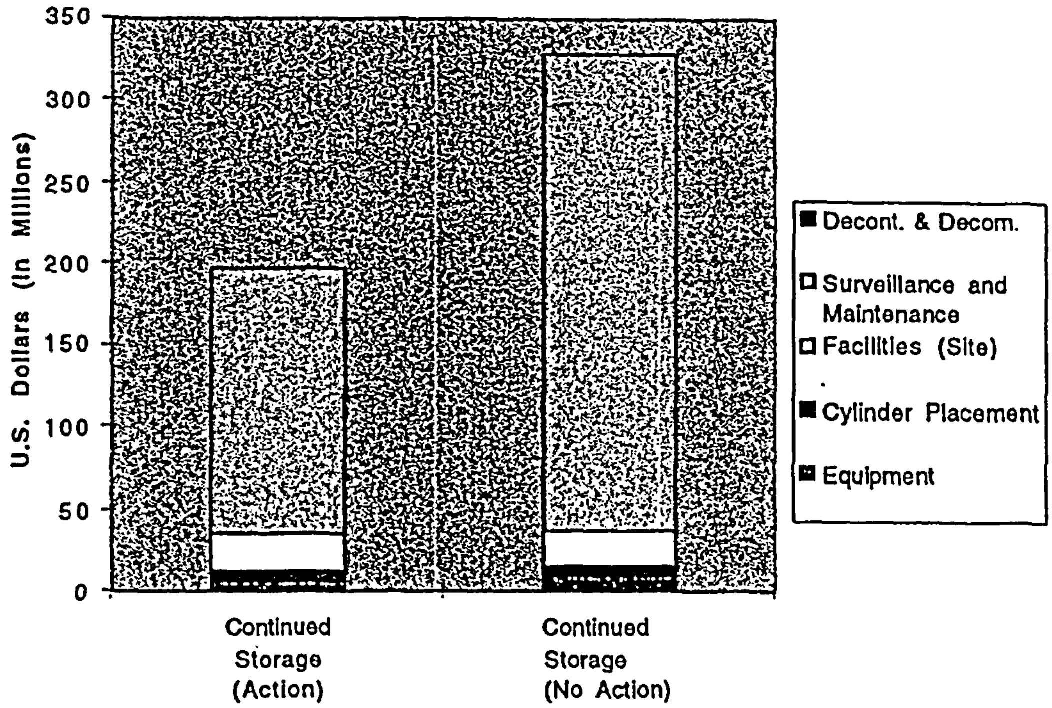
Unlike the other cost estimates, which are based on data contained in the *Engineering Analysis Report*, this cost estimate was derived from the Fiscal Year 1997 Baseline Plan for the sites and information provided by Lockheed Martin Energy Systems.

Table 4.13 and Figure 4.8 show the cost of continued storage for all alternatives. The first column gives the cost of continued storage for all alternatives other than the No Action alternative. The second column gives the No Action costs. Surveillance and maintenance account for more than 80% of the total cost for both.

Table 4.13 Cost Breakdown (in Millions of Dollars) for Continued Storage at Current Sites

	Continued Storage (Action)	Continued Storage (No Action)
Equipment	6.60	9.31
Cylinder Placement		
Materials	0.31	0.40
Utilities	0.00	0.00
Labor	6.89	6.89
Waste Management & Disposal	0.00	0.00
Subtotal	7.20	7.29
Facilities (Site)		
Engineering	3.89	3.89
Construction	14.71	14.71
Proj. Management	2.99	2.99
Subtotal	21.59	21.59
Surveillance and Maintenance		
Material	37.82	74.78
Utilities	1.78	3.93
Labor	118.63	204.98
Waste Management & Disposal	3.03	5.13
Subtotal	161.26	288.82
Decont. & Decom.	0.00	0.00
TOTAL	196.65	327.01

Figure 4.8 Total Costs for Continued Storage at Current Sites



5. COST ESTIMATION OF MANAGEMENT STRATEGIES

Six long-term management strategy alternatives are being considered. These strategies, which are described in Section 2.2, are listed below. The conversion options associated with each alternative are also identified.

- No action alternative
- Long-term storage as UF_6 in buildings or a mined cavity
- Long-term storage as oxide in buildings, vaults, or a mined cavity
  - U_3O_8 Defluorination with AHF production
  - U_3O_8 Defluorination with HF neutralization
  - UO_2 Gelation
- Use as uranium dioxide in DUCRETE™ for shielding applications
  - UO_2 Dry process with AHF production
  - UO_2 Dry process with HF neutralization
  - UO_2 Gelation
- Use as Metal for shielding applications
  - Batch metallothermic reduction
  - Continuous metallothermic reduction
- Disposal
  - U_3O_8 Defluorination with AHF production
  - U_3O_8 Defluorination with HF neutralization
  - UO_2 Gelation

The total cost for each management strategy is reported twice in this section by considering the lowest- and highest-cost options within each category included in a management strategy alternative. First, a low-cost scenario was considered that assumes (1) shipping is done by rail; (2) nonconforming cylinders are placed in a cylinder overcontainer in preparation for shipment; (3) storage of UF_6, U_3O_8, and UO_2 is carried out in a building; and (4) disposal of U_3O_8 and UO_2 is in the bulk form in an engineered trench. Second, a high-cost scenario was considered that assumes (1) shipping is done by truck; (2) depleted UF_6 in nonconforming cylinders is transferred to new or conforming cylinders which meet the DOT requirement; (3) storage of UF_6, U_3O_8, and UO_2 is carried out in a mined cavity; and (4) disposal of U_3O_8 and UO_2 is in the grouted form in a mined cavity. By selecting the lowest- and highest-cost options within each category, a range of costs for implementing each management strategy alternative is developed. For the remainder of this report, the low-cost scenario is addressed unless otherwise specified.

The costs of the alternatives, for both low- and high-cost scenarios, are summarized in Tables 5.1 and 5.2. As in the preceding sections of this report, the discount rate used is

7% p.a. Table 5.1 represents the lower-cost range for all the alternative strategies, while Table 5.2 represents the higher-cost range. Table 5.1 indicates that the lowest-cost management strategy is the No Action alternative and the second lowest-cost alternative is long-term storage of depleted UF_6. Unlike the other alternatives, these do not involve conversion to another chemical form. Table 5.1 also indicates that the highest-cost alternative management strategy is use as DUCRETE™ if the UO_2 conversion is by the gelation process; however, the cost of use as DUCRETE™ falls significantly if conversion is by a dry process. Additionally, taking credit for the cask can further reduce the cost of this alternative (refer to Section 6.1.3).

Table 5.2 indicates that disposal in a mined cavity as grouted U_3O_8 using the defluorination with HF neutralization conversion option is the most costly alternative using the high-cost scenarios. It is noted that the No Action alternative is still the lowest-cost alternative and long-term storage of depleted UF_6 is still the second lowest-cost alternative. The No Action alternative is unique in that the low- and the high-cost scenarios are equal since it is simply continued storage of depleted UF_6 in the existing yards, and options for preparation for shipment, transportation, and conversion do not apply.

Figures 5.1 and 5.2 compare the total costs of each alternative management strategy for both the low- and high-cost scenarios. Figures 5.3 to 5.28 present the percentage of cost attributed to each option category (continued storage, transportation, conversion, use, long-term storage, and disposal) for each alternative strategy for both the low- and high-cost scenarios.

Table 5.1 Cost Breakdown (in Millions of Dollars) for the Low-Cost Alternative Management Strategies

DUF_6 Alternatives	Continued Storage	Transportation	Conversion	Use	Long-Term Storage	Disposal	TOTAL
No Action	327						327
DUF_6 Long Term Storage	197	172			214		583
Long-Term Storage as Oxide (U_3O_8 Defluorination w/AHF Prod.)	197	191	267		225		880
Long-Term Storage as Oxide (U_3O_8 Defluorination. w/HF Neutralization.)	197	191	325		225		938
Long-Term Storage as Oxide (UO_2 Gelation)	197	191	821		147		1,356
Use as Oxide (UO_2 Dry Process w/AHF Prod.)	197	200	347	856			1,600
Use as Oxide (UO_2 Dry Process w/HF Neutralization)	197	200	395	856			1,648
Use as Oxide (UO_2 Gelation)	197	201	821	856			2,075
Use as Metal (Batch Met. Reduction)	197	202	665	889			1,953
Use as Metal (Cont. Met. Reduction)	197	202	492	889			1,780
Disposal (U_3O_8 Defluorination. w/AHF Prod.)	197	191	267			155	810
Disposal (U_3O_8 Defluorination. w/HF Neutralization.)	197	191	325			155	868
Disposal (UO_2 Gelation)	197	191	821			123	1,332

Figure 5.1 Comparison of Total Costs of Alternative Management Strategies (Low-Cost Scenarios)

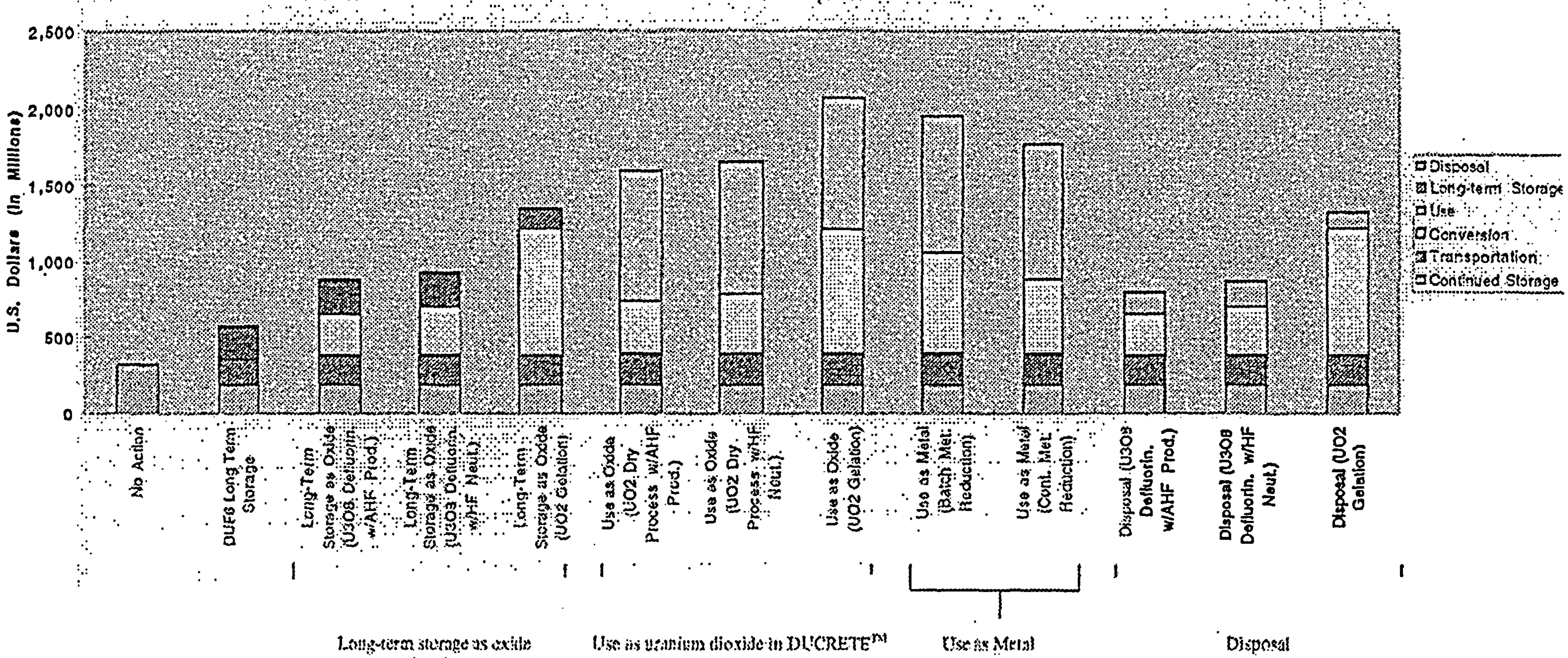


Table 5.2 Cost Breakdown (in Millions of Dollars) for the High-Cost Alternative Management Strategies

DUF_6 Alternatives	Continued Storage	Transportation	Conversion	Use	Long-term Storage	Disposal	TOTAL
No Action	327						327
DUF_4 Long Term Storage	197	677			644		1,518
Long-Term Storage as Oxide (U_3O_8 Defluorination. w/AHF Prod.)	197	702	267		731		1,897
Long-Term Storage as Oxide (U_3O_8 Defluorination. w/HF Neutralization.)	197	702	325		731		1,955
Long-Term Storage as Oxide (UO_2 Gelation)	197	702	821		483		2,203
Use as Oxide (UO_2 Dry Process w/AHF Prod.)	197	712	347	856			2,112
Use as Oxide (UO_2 Dry Process w/HF Neutralization.)	197	712	395	856			2,160
Use as Oxide (UO_2 Gelation)	197	711	821	856			2,585
Use as Metal (Batch Met. Reduction)	197	712	665	889			2,463
Use as Metal (Cont. Met. Reduction)	197	712	492	889			2,290
Disposal (U_3O_8 Defluorination. w/AHF Prod.)	197	702	267			1,395	2,561
Disposal (U_3O_8 Defluorination. w/HF Neutralization.)	197	702	325			1,395	2,619
Disposal (UO_2 Gelation)	197	702	821			830	2,550

Figure 5.2 Comparison of Total Costs of Alternative Management Strategies (High-Cost Scenarios)

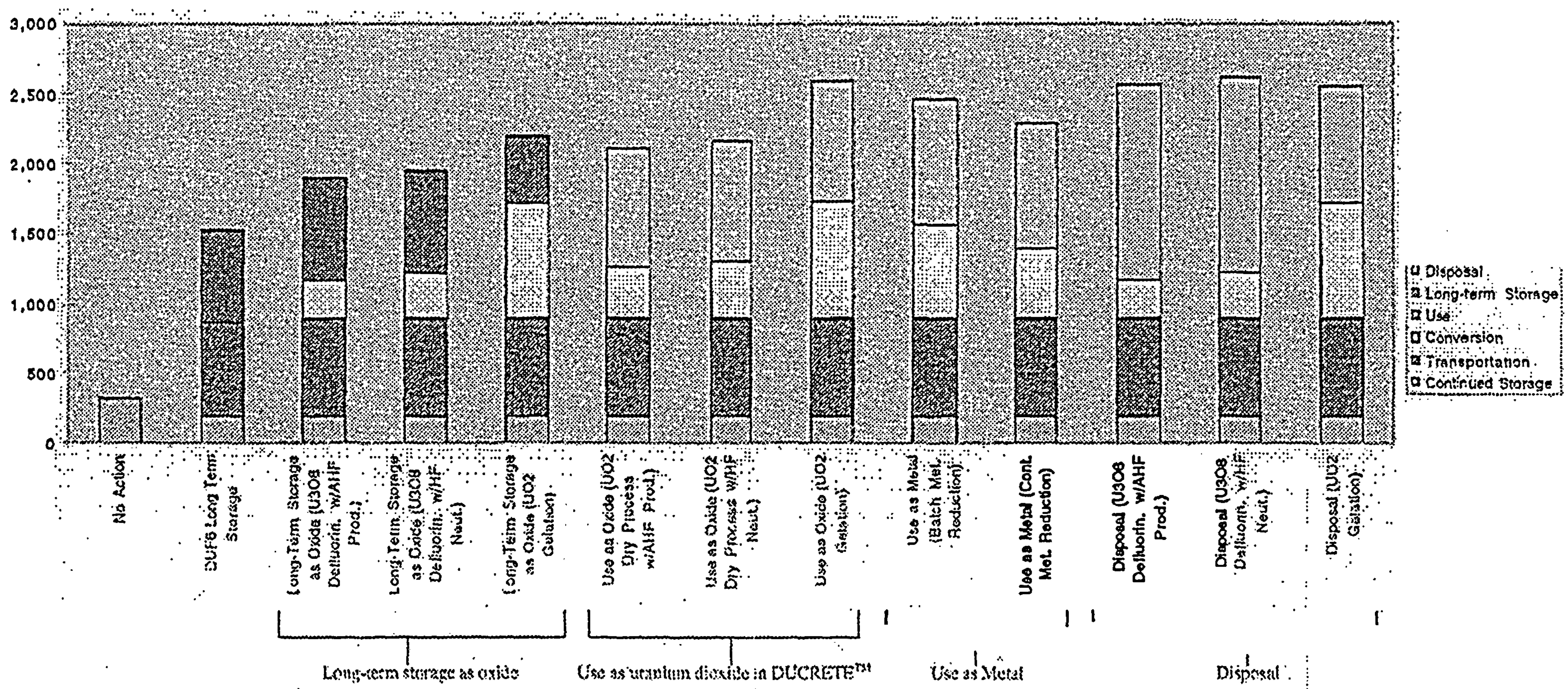


Figure 5.3 Low-Cost Breakdown for No Action ($327 Million)

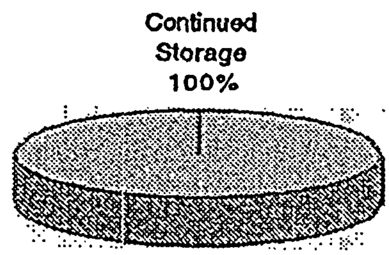


Figure 5.4 High-Cost Breakdown for No Action ($327 Million)

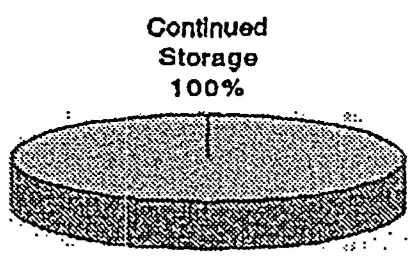


Figure 5.5 Low-Cost Breakdown for Long-Term Storage as DUF_6 ($583 Million)

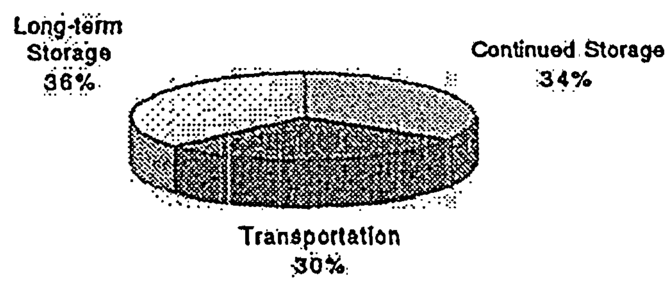


Figure 5.6 High-Cost Breakdown for Long-Term Storage as DUF_6 ($1518 Million)

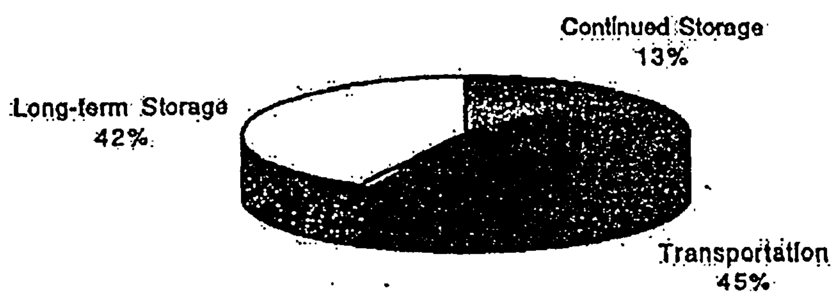


Figure 5.7 Low-Cost Breakdown for Long-Term Storage as Oxide - U_3O_8 Defluorination w/AHF Production ($880 Million)

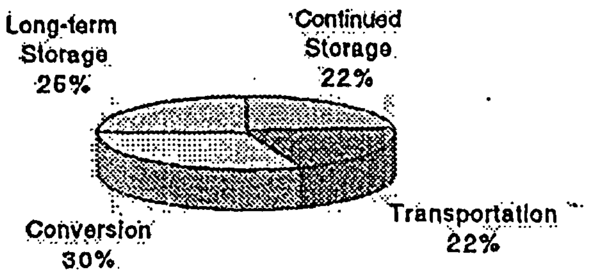


Figure 5.8 High-Cost Breakdown for Long-Term Storage as Oxide - U_3O_8 Defluorination w/AHF Production ($1897 Million)

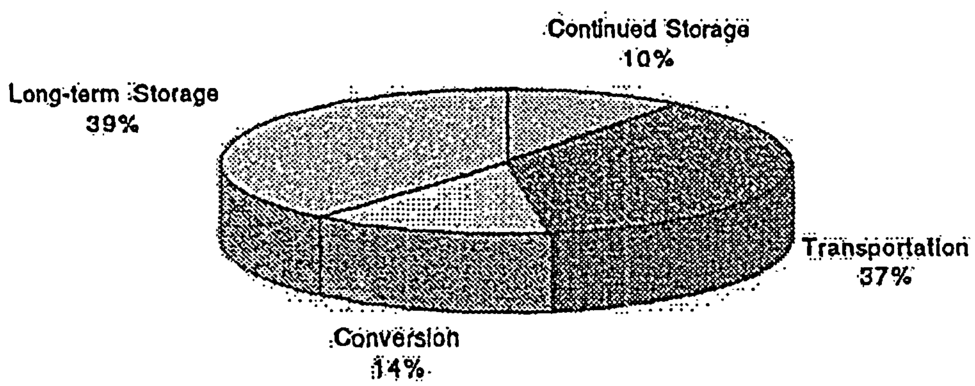


Figure 5.9 Low-Cost Breakdown for Long-Term Storage as Oxide - U_3O_8 Defluorination w/HF Neutralization ($938 Million)

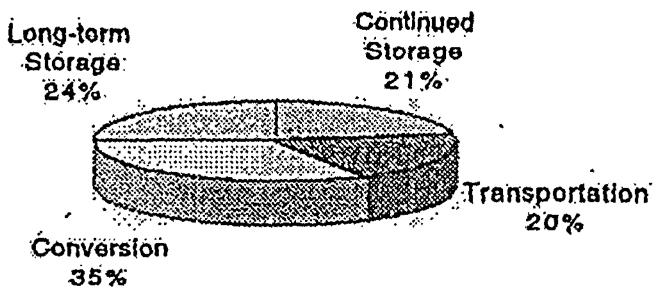


Figure 5.10 High-Cost Breakdown for Long-Term Storage as Oxide - U_3O_8 Defluorination w/HF Neutralization ($1955 Million)

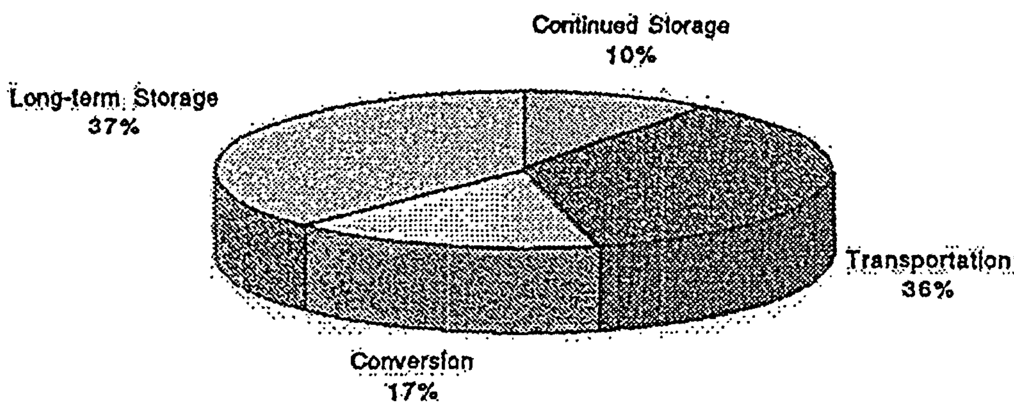


Figure 5.11 Low-Cost Breakdown for Long-Term Storage as Oxide - UO_2 Gelation ($1,356 Million)

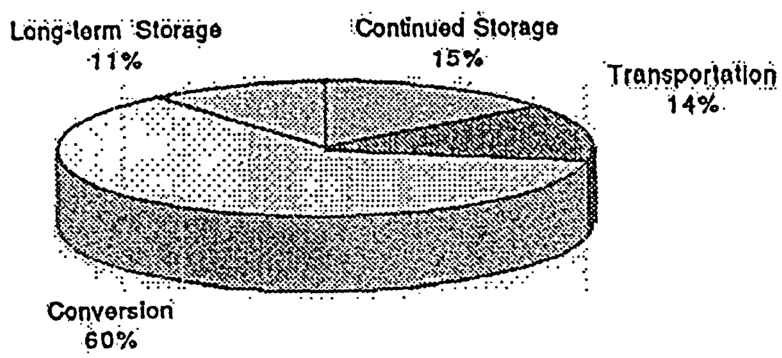


Figure 5.12 High-Cost Breakdown for Long-Term Storage as Oxide - UO_2 Gelation ($2,203 Million)

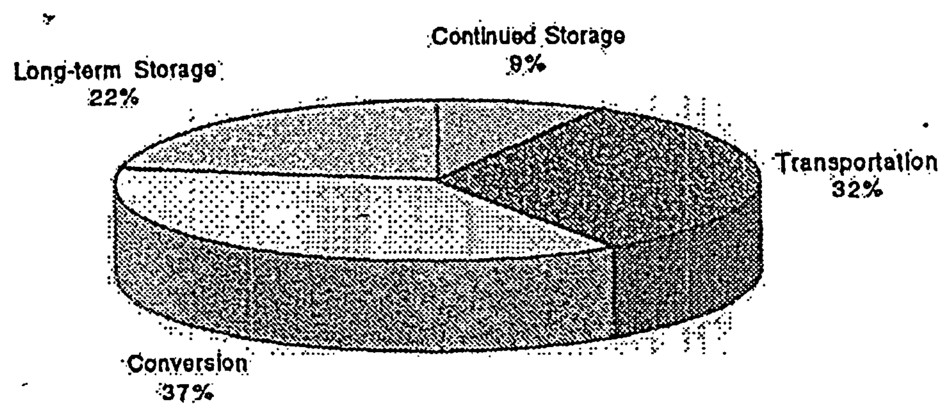


Figure 5.13 Low-Cost Breakdown for Use as Oxide - UO_2 Dry Process w/AHF Production ($1,600 Million)

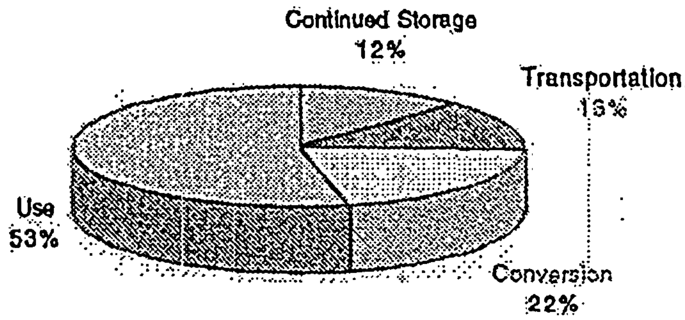


Figure 5.14 High-Cost Breakdown for Use as Oxide - UO_2 Dry Process w/AHF Production ($2,112 Million)

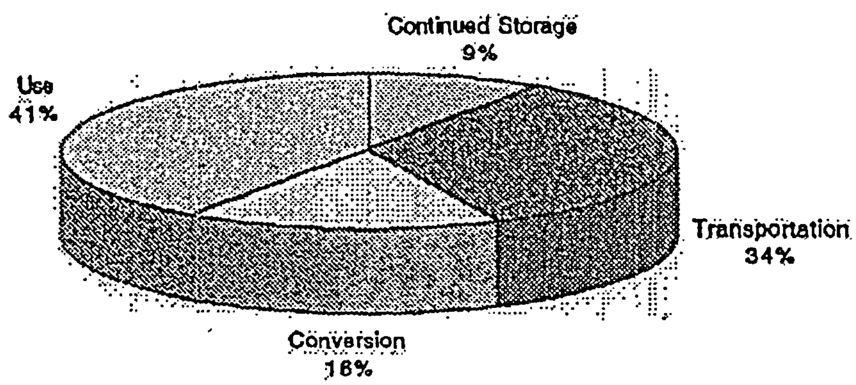


Figure 5.15 Low-Cost Breakdown for Use as Oxide - UO_2 Dry Process w/HF Neutralization ($1,648 Million)

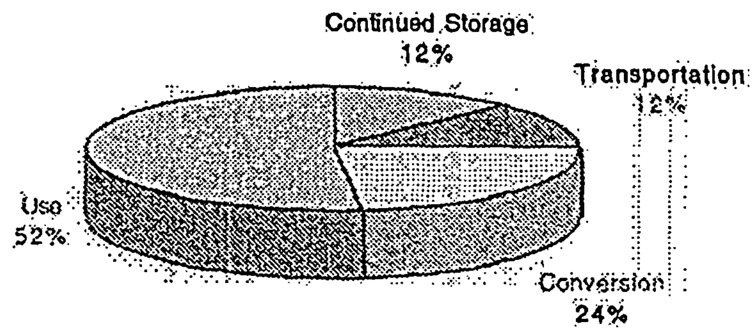


Figure 5.16 High-Cost Breakdown for Use as Oxide - UO_2 Dry Process w/HF Neutralization ($2,160 Million)

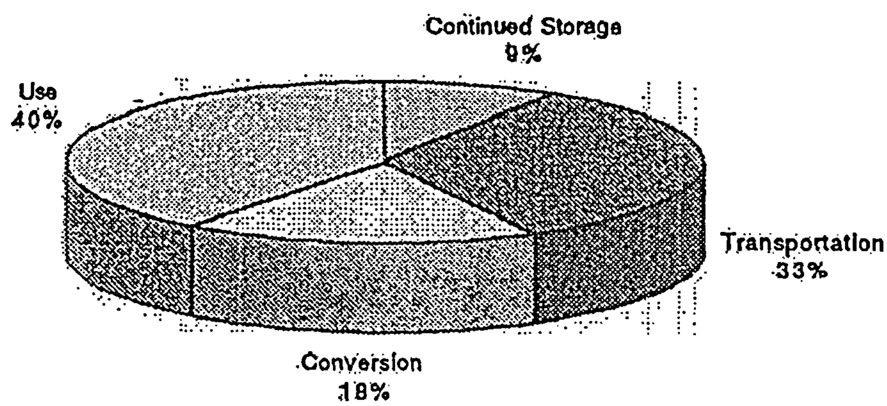


Figure 5.17 Low-Cost Breakdown for Use as Oxide - UO_2 Gelation ($2,075 Million)

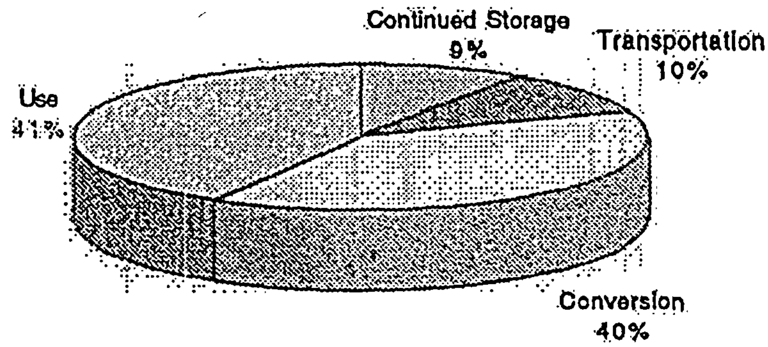


Figure 5.18 High-Cost Breakdown for Use as Oxide - UO_2 Gelation ($2,585 Million)

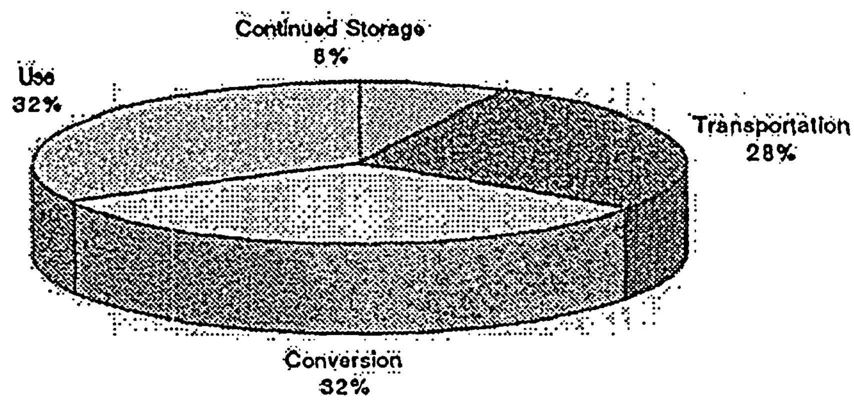


Figure 5.19 Low-Cost Breakdown for Use as Metal - Batch Metallothermic Reduction ($1,953 Million)

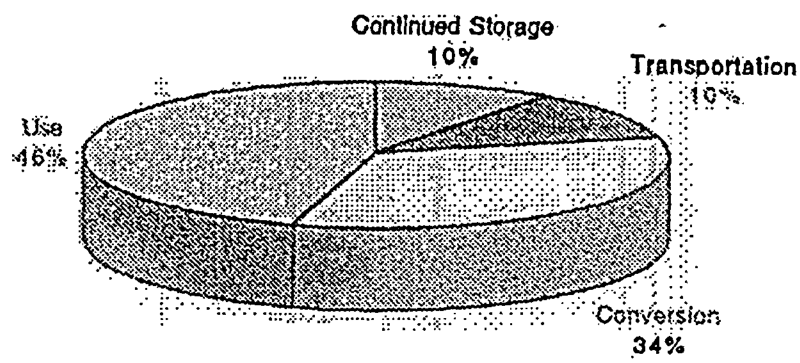


Figure 5.20 High-Cost Breakdown for Use as Metal - Batch Metallothermic Reduction ($2,463 Million)

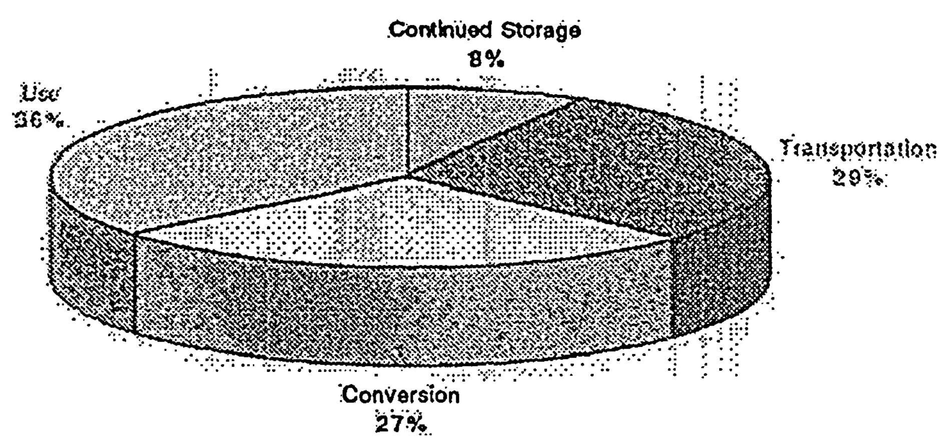


Figure 5.21 Low-Cost Breakdown for Use as Metal - Continuous Metallothermic Reduction ($1,780 Million)

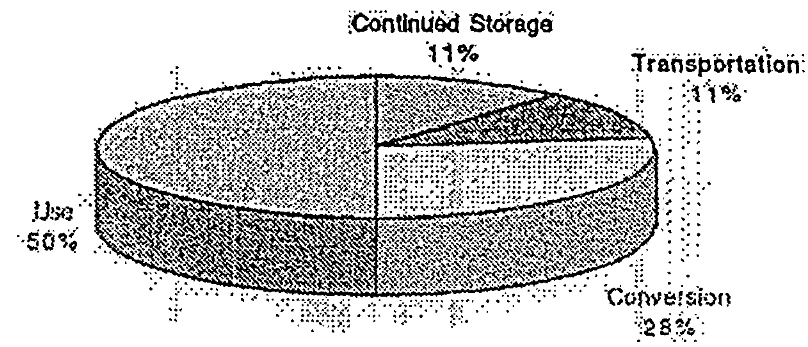


Figure 5.22 High-Cost Breakdown for Use as Metal - Continuous Metallothermic Reduction ($2,290 Million)

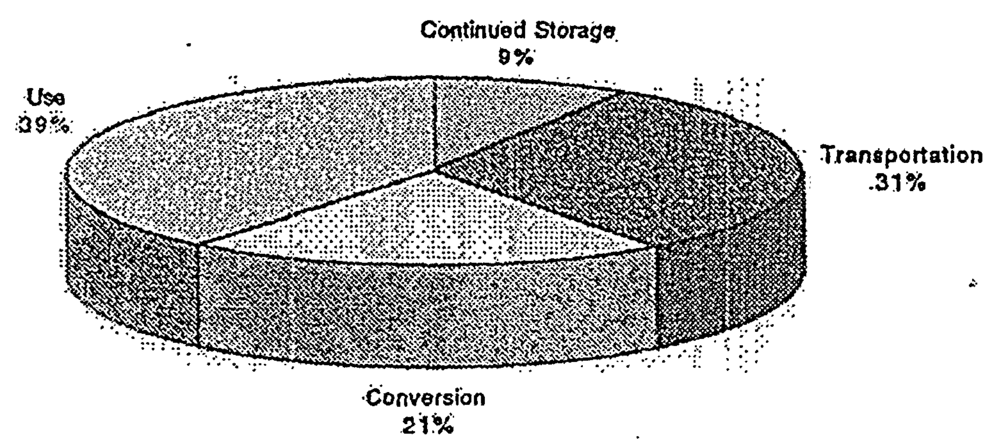


Figure 5.23 Low-Cost Breakdown for Disposal as Oxide - U_3O_8 Defluorination w/AHF Production ($810 Million)

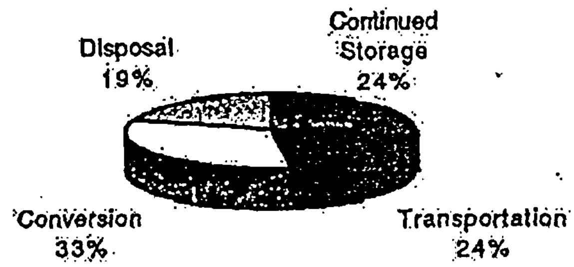


Figure 5.24 High-Cost Breakdown for Disposal as Oxide - U_3O_8 Defluorination w/AHF Production ($2,561 Million)

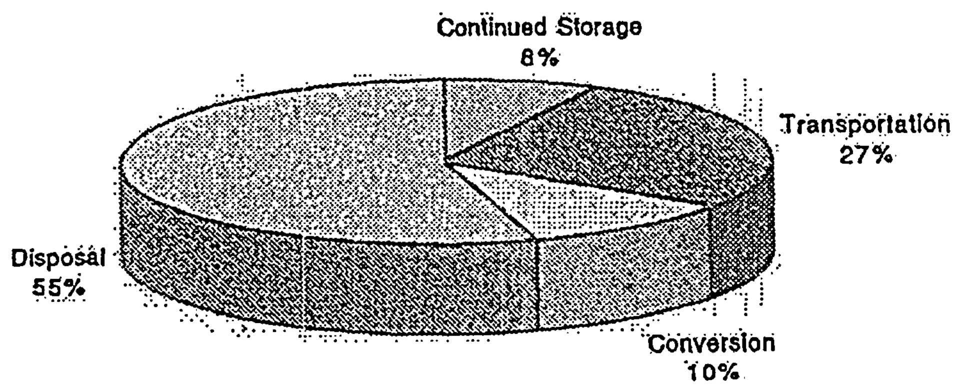


Figure 5.25 Low-Cost Breakdown for Disposal as Oxide - U_3O_8 Defluorination w/HF Neutralization ($868 Million)

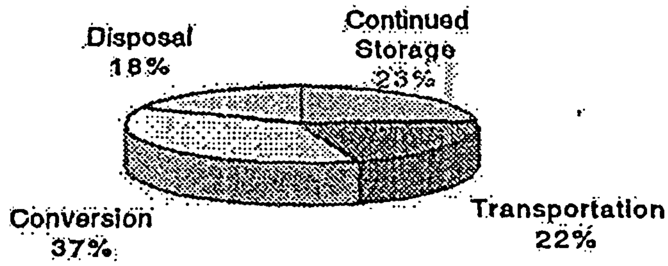


Figure 5.26 High-Cost Breakdown for Disposal as Oxide - U_3O_8 Defluorination w/HF Neutralization ($2,619 Million)

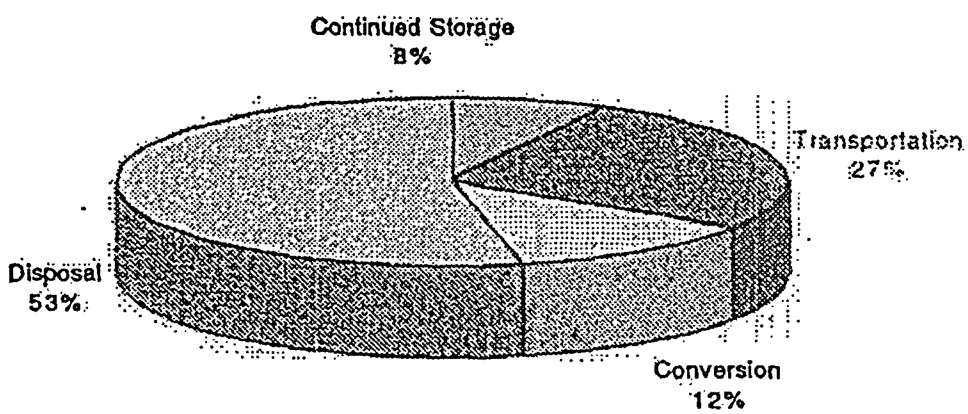


Figure 5.27 Low-Cost Breakdown for Disposal as Oxide - UO_2 Gelation ($1,332 Million)

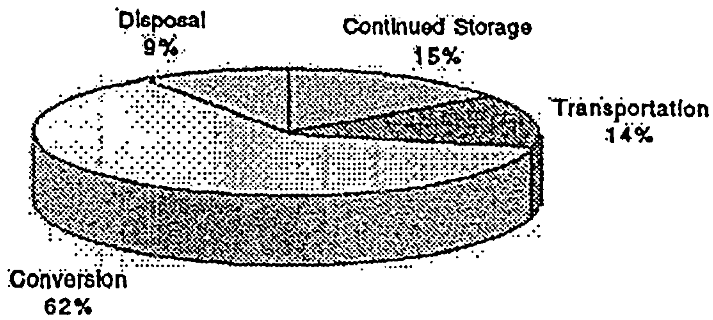
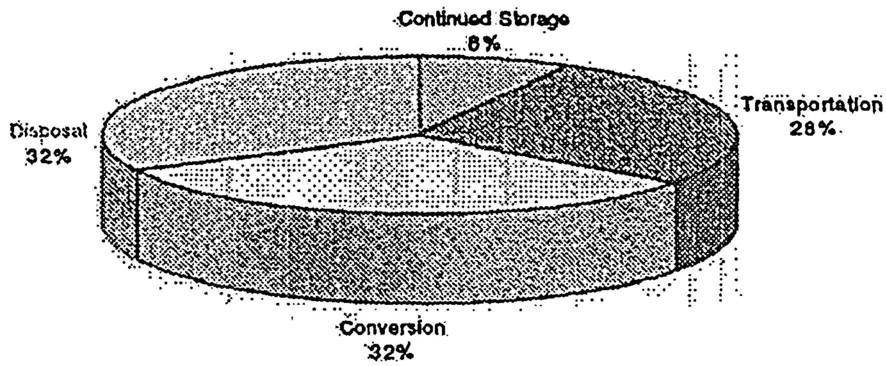


Figure 5.28 High-Cost Breakdown for Disposal as Oxide - UO_2 Gelation ($2,550 Million)



6. ANALYSIS OF SENSITIVITIES, RISKS, AND VULNERABILITIES

In addition to the reference cases treated in Chapters 4 and 5, there are sensitivity cases, performance risks, and vulnerabilities that need to be considered because they can make the cost outcome substantially different from that found for the reference cases. Sensitivity analyses were performed in accordance with OMB Circular No. A-94 guidance to determine how sensitive the costs of the alternative strategies were to changes in assumptions for various input parameters. The results are presented in Section 6.1.

In Section 6.2, Performance Risk, uncertainties in facility operating conditions and their potential cost impacts are discussed. For purposes of this discussion, performance risks are defined as failures of equipment and systems to perform up to the levels specified by their designers and causing them to operate below design specifications or to require additional process equipment in order to meet product quality requirements.

Process vulnerabilities to changes in the external environment in which the facility operates are the focus of Section 6.3. The facility may exactly meet its design goals, for example, but may not be allowed to dispose of a major processing waste as planned. Cost impacts due to external regulations affecting the use of major by-products or the disposal of large waste streams are discussed in Section 6.3.

Performance risks and vulnerabilities are alike in that they result from insufficient information being available to the facility designers. They differ in that performance risks can be reduced to as low a level as desired by early expenditures on developing and demonstrating the technology and the equipment. Vulnerabilities, since they result from changes in the legal and regulatory environment, cannot be controlled by the process designer or facility operator.

6.1 Sensitivity Analyses

Sensitivity to variations in discount rate, transportation distance, shielding cask values, product density, and facility throughput are presented in this section.

6.1.1 Effect of Discount Rate

All costs were estimated in first-quarter 1996 dollars and discounted to the start of the project according to OMB guidance:

> constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years.

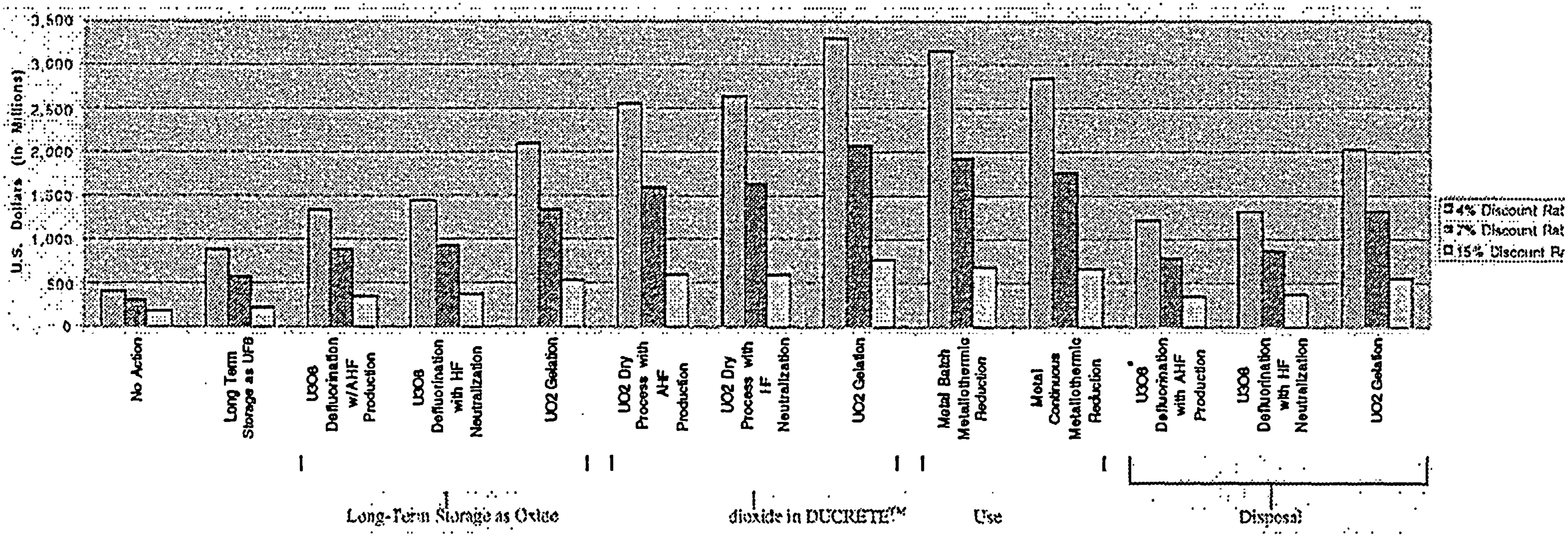
However, 7% may be too high if the long-term management of depleted UF_6 is viewed as an "internal" government investment that takes the form of decreased federal costs. Conversely, it may be too low if the management of the depleted UF_6 is privatized and private industry views the financial return as riskier than normal. Therefore, the effects on the present value of discount rates as low as 4% and as high as 15% were analyzed and the results summarized in Table 6.1 and Figure 6.1 (the low-cost scenario is addressed, as described in Chapter 5). Examination of Table 6.1 and Figure 6.1 shows that the ranking of strategies according to their cumulative discounted net costs is essentially unaffected by the choice of discount rates used for sensitivity analysis.

Table 6.1 Cost Breakdown (in Millions of Dollars) Based on Discount Rate

Strategy	Discount Rate 4.00%	7.00% *	15.00%
No Action	432	327	193
Long Term Storage as UF_6	903	583	241
Long-Term Storage as Oxide			
U_3O_x Defluorination w/AHF Production	1,357	880	365
U_3O_x Defluorination with HF Neutralization	1,462	938	378
UO_2 Gelation	2,099	1,356	554
Use as DUCRETE™			
UO_2 Dry Process with AHF Production	2,553	1,600	598
UO_2 Dry Process with HF Neutralization	2,643	1,648	607
UO_2 Gelation	3,309	2,075	775
Use as Metal			
Metal Batch Metallothermic Reduction	3,154	1,953	705
Metal Continuous Metallothermic Reduction	2,850	1,780	661
Disposal			
U_3O_x Defluorination with AHF Production	1,221	810	357
U_3O_x Defluorination with HF Neutralization	1,327	869	370
UO_2 Gelation	2,043	1,332	558

* Values in this column are for the reference case; they were taken from Table 5.1

Figure 6.1 Total Costs for Given Rates



6.1.2 Effect of Transportation Distances

The *Cost Analysis Report* and the draft PEIS assume a transportation distance of 1000 km whenever facilities are not collocated. The actual transportation distance may be more or less. In order to provide insights into the impacts of different transportation distances, the transportation cost components of the alternative management strategies for different distances are presented in Table 6.2 and Figure 6.2. All values presented in this table reflect the rail and overcontainer options.

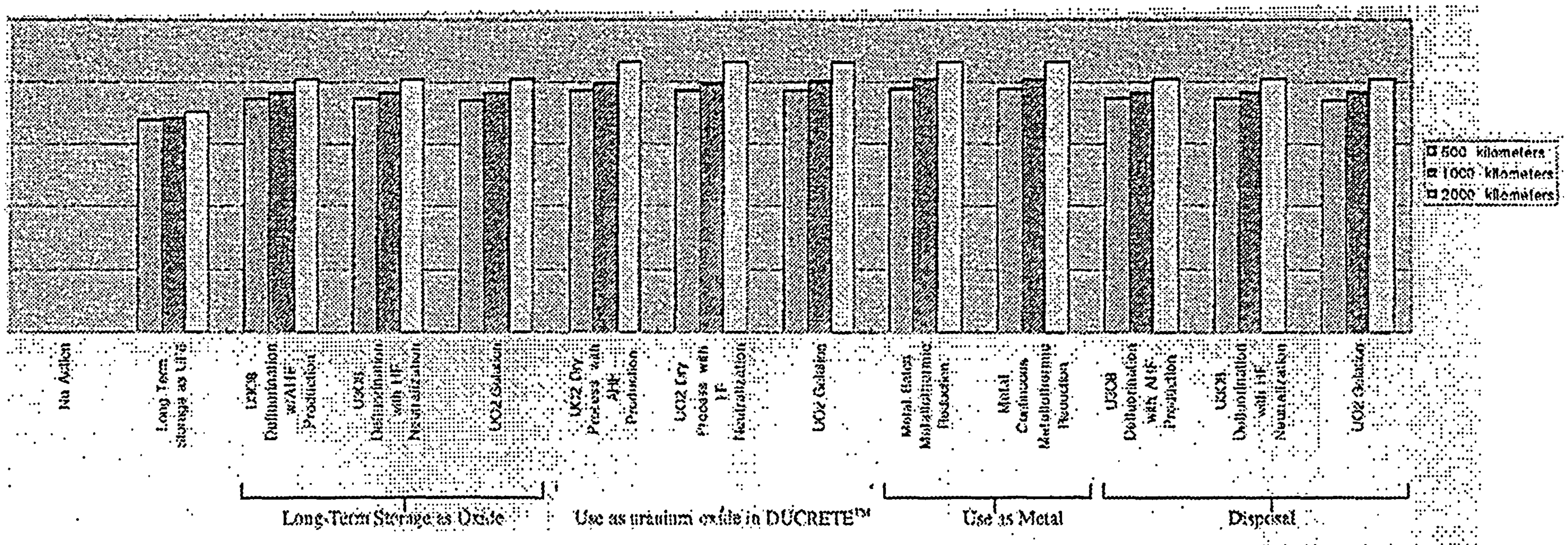
The loading, shipping, and unloading costs represent less than one quarter of the transportation costs. Changing the shipping distance does not change the ranking of strategies by cost. Distance affects only the shipping component of transportation costs, which will vary linearly with the distance between facilities. Total transportation costs are therefore relatively insensitive to distances between facilities. There is significant flexibility, therefore, in choosing off-site locations for conversion, manufacturing, storage, and disposal facilities. On-site locations, which would eliminate transportation costs, would require additional consideration. These cases would require site-specific analysis of distinctly sized facilities. The cost savings from avoiding transportation could readily be exceeded by the costs incurred from deploying multiple facilities.

Table 6.2 Transportation Cost Breakdown (in Millions of Dollars) based on Distance Between Facilities using Rail and Overcontainer Options

Strategy	Distance Between Facilities (in kilometers) 500	1000 *	2,000
No Action	0	0	0
Long Term Storage as UF_6	169	172	177
Long-Term Storage as Oxide			
U_3O_8 Defluorination w/AHF Production	186	191	202
U_3O_8 Defluorination with HF Neutralization	186	191	202
UO_2 Gelation	186	191	202
Use as DUCRETE™			
UO_2 Dry Process with AHF Production	193	200	215
UO_2 Dry Process with HF Neutralization	193	200	215
UO_2 Gelation	193	201	216
Use as metal			
Metal Batch Metallothermic Reduction	195	202	217
Metal Continuous Metallothermic Reduction	195	202	217
Disposal			
U_3O_8 Defluorination with AHF Production	186	191	202
U_3O_8 Defluorination with HF Neutralization	186	191	202
UO_2 Gelation	186	191	202

* Values in this column are for the reference case; they were taken from Table 4.6.

Figure 6.2 Total Transportation Costs for Given Distances between Facilities (Rail and Overcontainer Options)



6.1.3 Effect of Shielding Cask Values

As described in Section 2.1.5, the *Engineering Analysis Report* and the draft PEIS consider two alternatives involving the manufacture and use of depleted uranium for shielding: uranium dioxide (DUCRETE™) and uranium metal. The first option involves the manufacture of DUCRETE™ casks for dry storage of spent nuclear fuel disposal. The second involves the use of depleted uranium metal in the manufacture of annular shields for a multipurpose unit system for the storage, transportation, and disposal of spent nuclear fuel. The cost of these options was presented in Section 4.3 without taking any credit for the cask.

Both the *Cost Analysis Report* and the *Engineering Analysis Report* were based on the assumption that the demand for casks would match the supply, working off the inventory over 20 years. Based upon a throughput of 28,000 MT of depleted UF_6 per year, 480 DUCRETE™ and 453 depleted uranium metal casks would be produced annually. This approach is supported by the literature:

> The total quantity of DU metal needed for fabrication of 9500 containers is approximately 437,000 MTU. This total demand for DU metal exceeds the current DOE-owned inventory... (Herztler and Nishimoto, pp 33-34).

and

> Placing all of the U.S. spent fuel (about 86,000 metric tons) in DUCRETE casks would require about 9,500 casks and use most of the current DOE depleted uranium inventory (Powell, p. 2).

If depleted uranium or DUCRETE™ were manufactured into shielding casks for the storage of spent nuclear fuel, some price could be charged to the power reactor operator for such casks. This charge would off-set a portion of the costs incurred by management strategies for using depleted UF_6 whose end product is a cask. The revenue to the depleted UF_6 management enterprise from this charge should be taken into account, just as revenues from by-product AHF or CaF_2 sales are folded into the present-value evaluations presented in Chapters 4 and 5.

Casks made from depleted uranium metal or DUCRETE™ may have benefits to reactor operators that would make them more attractive to use (and thus command a higher price) than conventional concrete casks. These benefits might include potential reductions in transportation costs and cask handling operations. For example, a DUCRETE™ cask could be loaded directly in the spent nuclear fuel pool, whereas the current plan is to use a separate transfer cask because a conventional concrete cask is too large to fit into the storage pool. Additionally, it is possible that the depleted uranium cask could eventually be disposed with the spent fuel at the repository. However, these added benefits are speculative at the present time. The focus of this section is to make an initial assessment of the off-setting revenues resulting from cask production. This estimate will then be used in the life-cycle cost analysis for strategies leading to manufactured depleted uranium metal or DUCRETE™ casks to test the sensitivity of life-cycle costs to the cask value.

The economic differences between a DUCRETE™ spent nuclear fuel storage cask and a conventional concrete storage cask are summarized in the report, *Comparative Economics for DUCRETE Spent Fuel Storage Cask Handling, Transportation, and Capital Requirements*. The conventional concrete cask system considered in the report is the NRC-licensed Sierra Nuclear Corporation Ventilated Storage Cask, with an estimated cost for

materials of about $200,000, excluding such elements as engineering design and project management (Powell 1995).

Another NRC-licensed concrete cask is the Vector Fuels Division's NUHOMS concrete horizontal storage module. In the *Depleted Uranium Concrete Container Feasibility Study* (Haeslig 1994), the estimated cost for the concrete module of this storage system is $150,000. It is noted that an inner metal multipurpose canister system is needed to contain the spent nuclear fuel stored in any of the dry concrete storage systems. Similar economic data for the multipurpose unit system were not discovered. Accordingly, a sensitivity analysis assuming a cask credit of $150,000 and $200,000 per cask for both the DUCRETE™ and metal shielding applications was conducted.

As shown in Table 6.3, a cask credit of $150,000 and $200,000 per cask would reduce the life-cycle costs of the shielding options by about 40-60%. The cost of complete management strategy alternatives is presented in Chapter 5 of this *Cost Analysis Report*. These costs range from about $1,600 to $2,600 million (7% p.a. discount rate) for the shielding alternative without the cask credit. Total management strategy alternative costs would be reduced about $370-$550 million (7% p.a. discount rate) or 14-34% with the assumed cask credit.

Table 6.3 Sensitivity Analysis for Depleted Uranium Shielding Applications - Cask Credit

	DUCRETE™ Shielding Applications	Metal Shielding Applications
Number of casks manufactured		
per year	480	453
total, in 20 year project	9,600	9,060
Annual credit from sale of casks (millions)		
@ $0.15 million/shield	$72.00	$67.95
@ $0.2 million/shield	$96.00	$90.60
Cumulative present value credit from sale of casks (millions)		
@ $0.15 million/shield	$362.39	$342.00
@ $0.2 million/shield	$483.18	$456.00
Cumulative present value of shielding option (millions)		
With no credit for sale of casks (reference case)*	$856.30	$889.30
With credit of $0.15 million/cask	$493.91	$547.30
With credit of $0.20 million/cask	$373.12	$433.30

* Values in this row are for the reference case; they were taken from Table 4.10.

6.1.4 Effect of Density on UO_2 Storage and Disposal Options

The costs for the UO_2 storage and disposal options (Chapter 4) and their associated strategies (Chapter 5) are based on the gelation process for the conversion of UF_6 to dense

UO_2. The gelation process produces small spheres with a higher bulk density than the conventional UO_2 process, which produces pellets. This leads to a reduction in storage and disposal volume requirements, and therefore the gelation process minimizes the costs for the storage and disposal options involving the oxide. However, the gelation process is substantially more expensive than conversion to UO_2 pellets or U_3O_8 powder. Because the higher conversion cost of the gelation process does not off-set its lower storage and disposal option costs, the storage and disposal strategies based on U_3O_8 have a significantly lower cost (Chapter 5).

Bottom-up storage and disposal costs were not determined for UO_2 pellets, which have a bulk density and a conversion cost between that for U_3O_8 powder and that for UO_2 produced by the gelation process. An approximate scaling analysis was used to estimate the storage and disposal option costs for ungrouted UO_2 pellets. Within the estimating uncertainties, no significant differences were found in the strategy costs for storage and disposal of ungrouted UO_2 pellets and ungrouted U_3O_8 powder. Thus, storage and disposal of UO_2 pellets as a variation on the long-term management strategies for storage and disposal as an oxide are suitably contained within the options analyzed.

6.1.5 Effect of Facility Throughput

A period of 20 years was assumed to disposition the entire depleted uranium stockpile (about 560,000 MT UF_6 in 46,422 cylinders). This corresponds to an annual throughput rate of 28,000 MT of UF_6 or about 19,000 MT of uranium. Each option was evaluated at this rate, assuming that a single alternative would be selected. It is possible, however, that a hybrid of alternatives will be implemented. The need for parametric analysis of other options being considered for the long-term management of depleted UF_6 was determined after the end of the scoping period for the PEIS (March 25, 1996). The following options were selected for parametric analyses:

- Conversion to U_3O_8: defluorination with anhydrous hydrogen fluoride (AHF)
- Conversion to UO_2: ceramic UO_2 with AHF
- Conversion to uranium metal by continuous metallothermic reduction
- Manufacture and use as shielding (DUCRETE™ and metal)
- Storage in buildings as UO_2 and UF_6
- Disposal in a mined cavity as bulk U_3O_8

Key engineering and cost data elements for facilities that are sized for 50% and 25% of the reference capacity case (28,000 MT/year of depleted UF_6) were evaluated. These smaller facilities are assumed to be deployed on the same schedule as the reference facility and operate at throughputs of 14,000 MT/year and 7,000 MT/year, respectively, for 20 years. A summary of the results of these analyses is presented in Tables 6.4 to 6.11, and Figures 6.3 to 6.6. A discount rate of 7% p.a. is assumed.

As shown by these tables, reducing the throughput does not result in a corresponding cost reduction of the same magnitude. This is expected, on the basis of economy of scale considerations; however, the magnitude of this effect depends strongly on the specific option. For the conversion options, the present-value cost drops about 16%, on average, when the throughput is halved from the reference capacity. For the storage options, the equivalent reduction is about 34% on average. This significant difference reflects the greater modularity of the storage facility designs. These studies of throughput variations show that hybrid alternatives would likely have a higher total cost than a single alternative. For example, a hybrid which involves converting the depleted UF_6 to UO_2 and using half

in DUCRETE™ shielding applications and storing half would have a higher cost over the time frame considered than storing it all as oxide. Likewise, the cost could also be significantly higher for an alternative involving multiple sites for the same module. For example, the increase in conversion costs from converting the depleted UF_6 to UO_2 at two sites may not be off-set by the decrease in avoided transportation costs.

Table 6.4 Parametric Analysis of Conversion to U_3O_8: Defluorination w/AHF (in Millions of Dollars)

	25%	50%	100% *
Tech. Development	9.84	9.84	9.84
Process Equipment			
Engineering	3.26	3.64	4.74
Fabrications	7.96	8.88	11.91
Installation	3.78	4.21	5.19
Certification & Test	0.35	0.39	0.52
Subtotal	15.35	17.12	22.36
Process Facilities			
Engineering	6.88	8.29	10.16
Construction	20.01	24.12	29.56
Proj. Management	4.48	5.40	6.61
Subtotal	31.37	37.81	46.33
Balance of Plant			
Engineering	4.22	4.96	6.40
Construction	12.28	14.44	18.63
Proj. Management	2.75	3.23	4.17
Subtotal	19.25	22.63	29.20
Regulatory Compliance	22.70	22.70	22.70
Operations and Maintenance			
Material	29.85	37.79	52.71
Utilities	11.73	12.12	12.83
Labor	123.09	127.16	134.68
Waste Management & Disposal	4.35	6.92	11.86
By-product Revenue	-19.33	-38.66	-77.32
Subtotal	149.69	145.33	134.76
Decont. & Decom.	1.18	1.39	1.76
TOTAL	249.38	256.82	266.95

* Values in this column are for the reference case; they were taken from Table 4.8

Table 6.5 Parametric Analysis of Conversion to UO_2: Ceramic UO_2 w/AHF (in Millions of Dollars)

	25%	50%	100% *
Tech. Development	13.94	13.94	13.94
Process Equipment			
Engineering	5.50	6.26	7.74
Fabrications	13.10	15.05	18.96
Installation	6.70	7.47	8.91
Certification & Test	0.57	0.66	0.83
Subtotal	25.87	29.44	36.44
Process Facilities			
Engineering	9.83	12.52	14.91
Construction	28.61	36.44	43.39
Proj. Management	6.40	8.15	9.71
Subtotal	44.84	57.11	68.01
Balance of Plant			
Engineering	5.10	6.18	7.76
Construction	14.85	17.97	22.57
Proj. Management	2.71	3.28	4.12
Subtotal	22.66	27.43	34.45
Regulatory Compliance	22.70	22.70	22.70
Operations and Maintenance			
Material	38.85	49.67	66.12
Utilities	13.45	13.84	14.55
Labor	141.13	145.20	152.72
Waste Management & Disposal	4.81	7.01	12.47
By-product Revenue	-19.33	-38.65	-77.31
Subtotal	178.91	177.07	168.55
Decont. & Decom.	1.69	2.06	2.51
TOTAL	310.61	329.75	346.60

* Values in this column are for the reference case; they were taken from Table 4.8

Table 6.6 Parametric Analysis of Conversion to Metal by Continuous Metallothermic Reduction (in Millions of Dollars)

	25%	50%	100% *
Tech. Development	20.50	20.50	20.50
Process Equipment			
Engineering	4.72	5.55	6.52
Fabrications	10.63	12.75	15.22
Installation	6.29	7.19	8.20
Certification & Test	0.46	0.56	0.66
Subtotal	22.10	26.05	30.60
Process Facilities			
Engineering	11.59	13.47	16.09
Construction	33.70	39.18	46.82
Proj. Management	7.54	8.77	10.47
Subtotal	52.83	61.42	73.38
Balance of Plant			
Engineering	5.32	6.39	8.22
Construction	15.48	18.59	23.91
Proj. Management	3.46	4.16	5.35
Subtotal	24.26	29.14	37.48
Regulatory Compliance	22.70	22.70	22.70
Operations and Maintenance			
Material	70.74	108.86	171.76
Utilities	12.00	12.39	13.30
Labor	125.91	129.98	139.57
Waste Management & Disposal	3.25	4.30	6.14
By-product Revenue	-6.53	-13.05	-26.11
Subtotal	211.90	255.53	330.77
Decont. & Decom.	1.78	2.09	2.54
TOTAL	349.54	404.38	491.86

* Values in this column are for the reference case; they were taken from Table 4.8

Figure 6.3 Parametric Analysis of Conversion Options

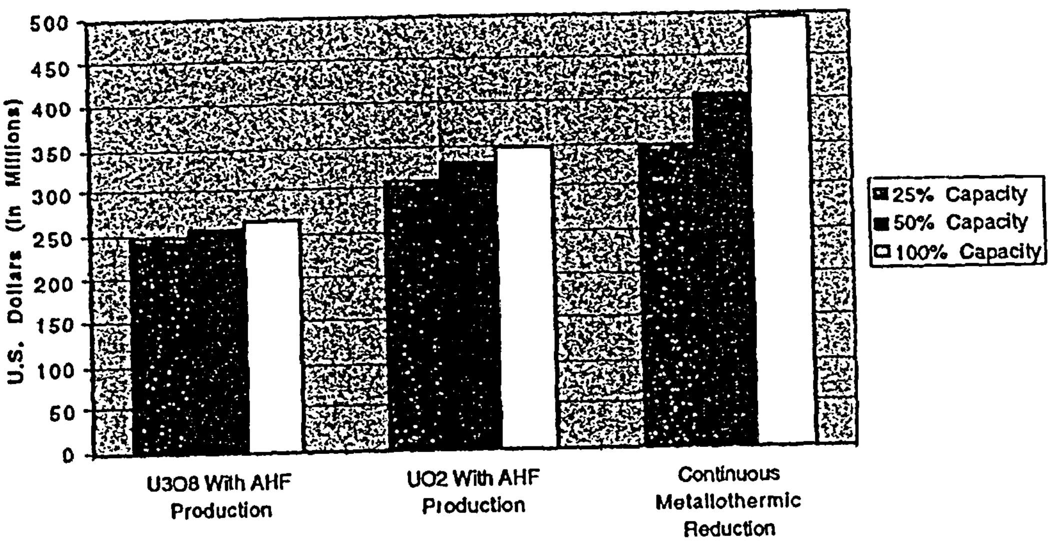


Table 6.7 Parametric Analysis of Manufacture and Use as Metal Shielding (in Millions of Dollars)

	25%	50%	100% *
Engineering Development	16.40	16.40	16.40
Manufacturing Equipment			
Engineering	2.47	3.14	4.11
Fabrication	6.93	8.80	11.55
Installation	1.94	2.45	3.19
Certification and Test	0.33	0.39	0.51
Subtotal	11.67	14.78	19.36
Manufacturing Facilities			
Engineering	5.43	6.41	7.64
Construction	15.81	18.68	22.26
Project Management	3.54	4.18	4.99
Subtotal	24.78	29.27	34.89
Balance of Plant			
Engineering	5.81	5.88	5.95
Construction	16.89	17.10	17.31
Project Management	3.79	3.83	3.88
Subtotal	26.49	26.81	27.14
Regulatory Compliance	17.43	17.43	17.43
Operations & Maintenance			
Materials	93.97	166.49	311.49
Utilities	30.71	36.11	42.30
Labor	301.37	354.37	415.13
Waste Management	1.29	1.96	3.70
Cask Credit	0.00	0.00	0.00
Subtotal	427.34	558.93	772.62
Decontamination & Decommissioning	1.13	1.27	1.46
TOTAL	525.24	664.89	889.30

* Values in this column are for the reference case; they were taken from Table 4.10

Table 6.8 Parametric Analysis of Manufacture and Use as Oxide Shielding (in Millions of Dollars)

	25%	50%	100% *
Engineering Development	6.56	6.56	6.56
Manufacturing Equipment			
Engineering	2.41	3.05	3.94
Fabrication	6.76	8.56	11.06
Installation	1.89	2.38	3.06
Certification and Test	0.32	0.38	0.49
Subtotal	11.38	14.37	18.55
Manufacturing Facilities			
Engineering	5.05	5.79	6.87
Construction	14.72	16.86	20.02
Project Management	3.30	3.78	4.49
Subtotal	23.07	26.43	31.38
Balance of Plant			
Engineering	4.83	4.88	4.94
Construction	14.06	14.21	14.36
Project Management	3.15	3.18	3.22
Subtotal	22.04	22.27	22.52
Regulatory Compliance	17.43	17.43	17.43
Operations & Maintenance			
Materials	88.41	157.59	296.05
Utilities	30.49	31.35	42.41
Labor	299.19	307.60	416.18
Waste Management	1.37	2.08	3.92
Cask Credit	0.00	0.00	0.00
Subtotal	419.46	498.62	758.56
Decontamination & Decommissioning	1.01	1.13	1.30
TOTAL	500.95	586.81	856.30

* Values in this column are for the reference case; they were taken from Table 4.10

Figure 6.4 Parametric Analysis of Use Options

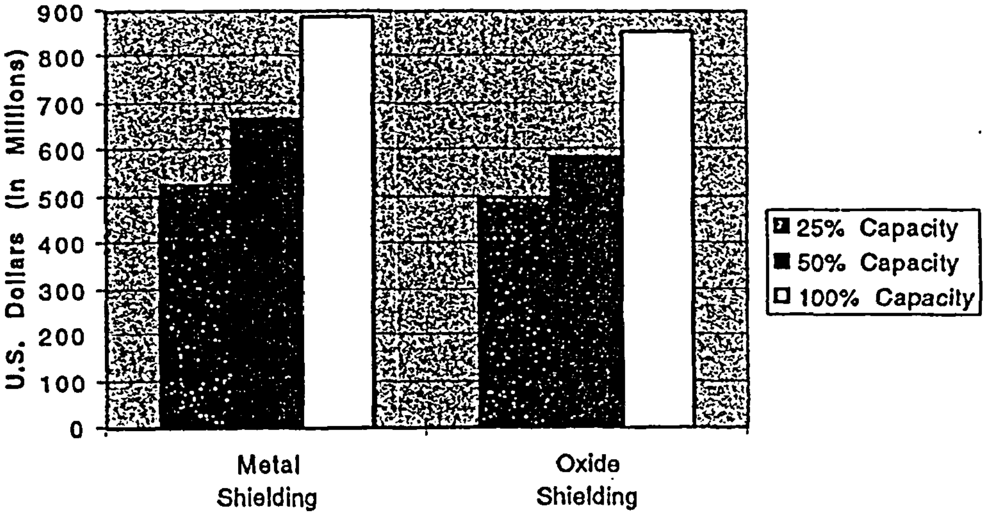


Table 6.9 Parametric Analysis of Storage in Buildings as UF_6 (in Millions of Dollars)

	25%	50%	100% *
Technology Development	0.82	0.82	0.82
Equipment			
Engineering	0.42	0.59	0.95
Fabrications	0.62	0.87	1.39
Installation	1.20	1.67	2.68
Certification & Test	0.03	0.04	0.07
Subtotal	2.27	3.17	5.09
Facilities			
Engineering	6.47	11.03	21.30
Construction	23.54	40.10	77.45
Proj. Management	4.30	7.32	14.13
Subtotal	34.31	58.45	112.88
Balance of Plant			
Engineering	1.00	1.26	1.58
Construction	3.65	4.59	5.74
Proj. Management	0.67	0.84	1.05
Subtotal	5.32	6.69	8.37
Regulatory Compliance	18.61	18.61	18.61
Operations and Maintenance			
Material	8.80	12.00	19.41
Utilities	0.90	1.33	2.12
Labor	24.46	31.88	47.03
Waste Management & Disposal	0.15	0.15	0.15
Subtotal	34.31	45.36	68.71
Decont. & Decom.	0.00	0.00	0.00
TOTAL	95.64	133.10	214.48

* Values in this column are for the reference case; they were taken from Table 4.11

Table 6.10 Parametric Analysis of Storage in Buildings as UO_2 (in Millions of Dollars)

	25%	50%	100% *
Technology Development	0.82	0.82	0.82
Equipment			
Engineering	0.27	0.30	0.38
Fabrications	0.65	0.73	0.94
Installation	0.49	0.55	0.71
Certification & Test	0.03	0.04	0.05
Subtotal	1.44	1.62	2.08
Facilities			
Engineering	4.57	7.04	11.91
Construction	16.62	25.61	43.32
Proj. Management	3.03	4.67	7.91
Subtotal	24.22	37.32	63.14
Balance of Plant			
Engineering	1.04	1.19	1.34
Construction	3.78	4.33	4.88
Proj. Management	0.69	0.79	0.89
Subtotal	5.51	6.31	7.11
Regulatory Compliance	18.61	18.61	18.61
Operations and Maintenance			
Material	5.35	6.15	8.05
Utilities	1.12	1.23	1.63
Labor	22.83	29.85	45.02
Waste Management & Disposal	0.13	0.13	0.13
Subtotal	29.43	37.36	54.83
Decont. & Decom.	0.00	0.00	0.00
TOTAL	80.03	102.04	146.59

* Values in this column are for the reference case; they were taken from Table 4.11

Figure 6.5 Parametric Analysis of Storage Options

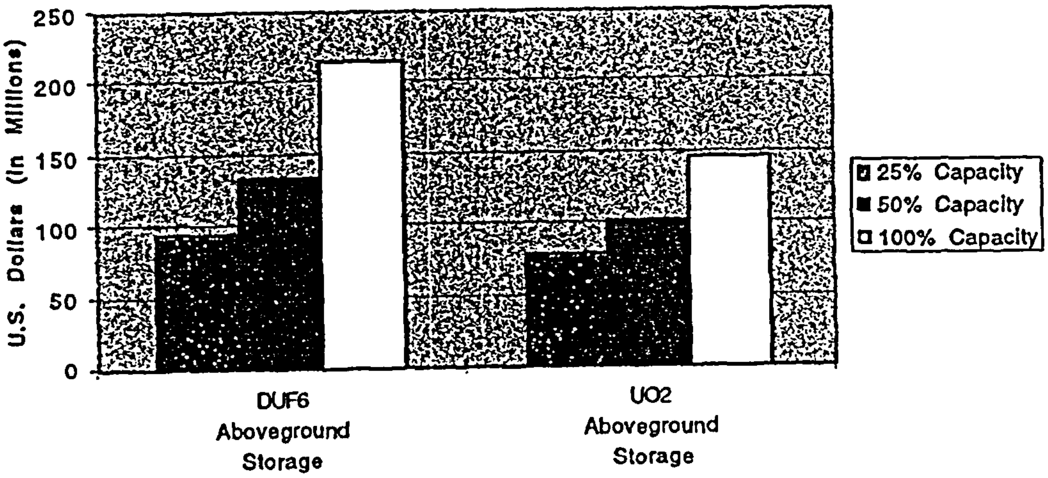


Table 6.11 Parametric Analysis of Disposal in a Mined Cavity as Bulk U_3O_8 (in Millions of Dollars)

Preparation	25%	50%	100% *
Technology Development	8.20	8.20	8.20
Equipment			
Engineering	0.00	0.00	0.00
Fabrications	0.00	0.00	0.00
Installation	0.00	0.00	0.00
Certification & Test	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00
Facilities			
Engineering	0.00	0.00	0.00
Construction	0.00	0.00	0.00
Proj. Management	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00
Balance of Plant			
Engineering	3.11	4.19	6.01
Construction	8.58	11.55	16.56
Proj. Management	2.00	2.69	3.86
Subtotal	13.69	18.43	26.43
Regulatory Compliance	2.02	2.02	2.02
Operations and Maintenance			
Material	0.07	0.10	0.14
Utilities	1.69	2.41	3.51
Labor	15.98	21.38	28.41
Waste Management & Disposal	0.54	0.74	1.17
Subtotal	18.28	24.63	33.23
Decont. & Decom.	0.37	0.46	0.60
Total Preparation Cost	42.56	53.74	70.48

* Values in this column are for the reference case; they were taken from Table 4.12

[Table 6.11 is continued on the next page.]

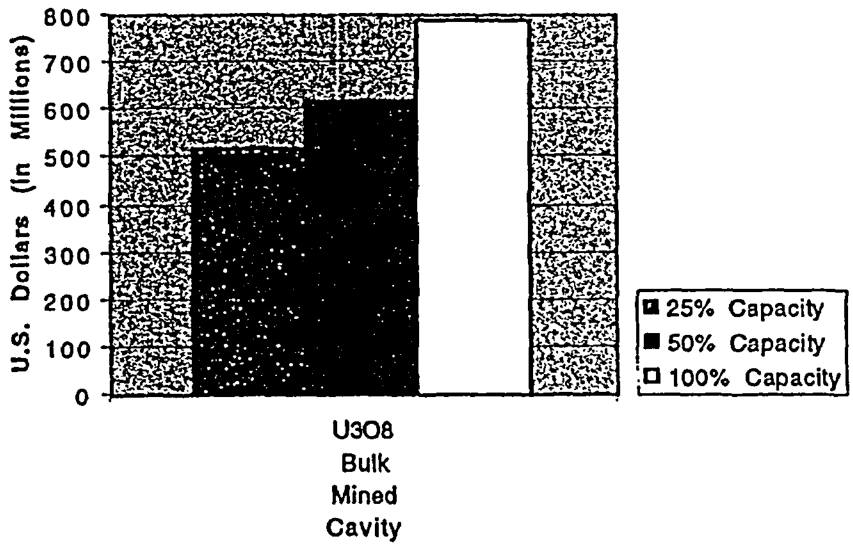
Table 6.11 Parametric Analysis of Disposal in a Mined Cavity as Bulk U_3O_8 (Continued)

	25%	50%	100% *
Facility			
Engineering	66.74	74.17	87.05
Construction	208.11	231.28	271.44
Project Management	38.74	43.06	50.53
Subtotal	313.59	348.51	409.02
Site Preparation & Restoration			
Engineering	3.46	3.54	3.62
Construction	12.57	12.88	13.18
Project Management	2.29	2.35	2.41
Subtotal	18.32	18.77	19.21
Emplacement & Closure			
Emplacement	12.44	18.12	28.49
Emplacement Support	63.03	103.16	183.46
Closure	26.78	29.67	36.93
Subtotal	102.25	150.95	248.88
Regulatory Compliance	40.35	40.35	40.35
Surveillance & Maintenance			
Materials	0.58	0.58	0.58
Labor	1.63	1.63	1.63
Subtotal	2.21	2.21	2.21
Total Facility Cost	476.72	560.79	719.67

	25%	50%	100%
GRAND TOTAL	519.28	614.53	790.15

* Values in this column are for the reference case; they were taken from Table 4.12.

Figure 6.6 Parametric Analysis of Disposal Options



6.2 Performance Risk

The cost effects due to uncertainties in the number of nonconforming cylinders and process and facility design are presented in this section.

6.2.1 Number of Nonconforming Cylinders

The number of depleted UF_6 cylinders that will not meet transportation requirements over the shipping time frame is uncertain. Changes in the number of such cylinders impact the costs of preparing the cylinders for off-site shipment. The preliminary estimate of the number of nonconforming cylinders is 19,200 at Paducah; 5,200 at Portsmouth; and 4,683 (the entire inventory) at K-25. The uncertainty in the number of nonconforming cylinders ranges from a low of one-half of these preliminary estimates to a high of all cylinders. It is anticipated that the range of uncertainty will change over time as estimates of the numbers of overpressured, overfilled, and substandard cylinders are refined and as cylinder conditions and regulatory requirements change.

	Reference		Low		High	
	Number of Non-Conforming Cylinders	Number of Conforming Cylinders	Number of Non-Conforming Cylinders	Number of Conforming Cylinders	Number of Non-Conforming Cylinders	Number of Conforming Cylinders
Portsmouth	5200	8188	2600	10788	13388	0
Paducah	19200	9151	9600	18751	28351	0
K-25	4683	0	2342	2341	4683	0
Total	29083	17339	14542	31880	46422	0

In order to analyze the impact of this uncertainty, the engineering analysis developed preconceptual designs for transfer facilities to handle three different throughput rates. The low-capacity case was 320 cylinders per year; the reference case was 960 cylinders per year; and the high-capacity case was 1,600 cylinders per year. The largest facility would be capable of transferring all the cylinders at Paducah, the site with the most cylinders (28,351). The smallest facility would be appropriate for transferring all the cylinders at K-25 (4,683) or all the projected nonconforming cylinders at Portsmouth (5,200) in fewer than 20 years. The cost of each of these three throughput rates was evaluated and used to interpolate or extrapolate costs for the low, reference, and high numbers of nonconforming cylinders.

Costs for preparing cylinders for shipment are, of necessity, site-specific. Based upon the cases analyzed above and the assumptions made concerning the number of nonconforming cylinders, the present value (7% p.a. discount rate) of the total costs for preparing the cylinders for shipment is presented in Tables 6.12, 6.13, and 6.14. The cost of preparing conforming cylinders for shipment is presented in Table 6.12. Tables 6.13 and 6.14 present the costs of the two options for preparing nonconforming cylinders for shipment, the cylinder overcontainer option and the transfer facility option. Since labor costs dominate the preparation for conforming cylinders (Table 6.12) and the overcontainer option (Table 6.13), for initial purposes all other costs for the low and high cases (where applicable) were equated to the reference values. The total cost for each option is the sum of the cost for preparing conforming cylinders for shipment and the cost of preparing nonconforming cylinders for shipment. For the overcontainer option, there is a slight variation in labor costs and costs for the overcontainers (which are reusable). For the

transfer facility option, a transfer facility sized according to the number of nonconforming cylinders is needed at each site.

There is a significant difference between the cost of preparing cylinders for shipment using the overcontainer and preparing them for shipment using the transfer facility. Total costs using the overcontainer for problem cylinders range from about $147 million (low-cost column in Table 6.12 plus low-cost column in Table 6.13) for 14,542 nonconforming and 31,880 conforming cylinders to about $171 million (high-cost column in Table 6.13) if all 46,422 cylinders were nonconforming. The number of nonconforming cylinders has a greater dollar impact on the transfer facility option, where total costs range from $609 million (low-cost column in Table 6.12 plus low-cost column in Table 6.14) to $706 million (high-cost column in Table 6.14). Clearly, what is most significant from a cost perspective is which option is chosen—the overcontainer or the transfer facility.

Table 6.12 Cost Breakdown (in Millions of Dollars) for Preparing Conforming Cylinders

	Reference	Low	High
Inspection and retrieval equipment			
Engineering	0.17	0.17	0.00
Fabrication	1.39	1.39	0.00
Certification	0.07	0.07	0.00
Subtotal	1.63	1.63	0.00
Handling fixtures			
Engineering	0.06	0.06	0.00
Fabrication	0.47	0.47	0.00
Certification	0.02	0.02	0.00
Subtotal	0.55	0.55	0.00
Shipping fixtures			
Engineering	0.02	0.02	0.00
Fabrication	0.16	0.16	0.00
Certification	0.01	0.01	0.00
Subtotal	0.19	0.19	0.00
Facilities			
Engineering	0.00	0.00	0.00
Construction	0.00	0.00	0.00
Project management	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00
Regulatory compliance	1.13	1.13	0.00
Operations and maintenance			
Materials	1.64	1.64	0.00
Utilities	0.01	0.01	0.00
Labor	44.27	81.35	0.00
Waste management and disposal	0.19	0.19	0.00
Subtotal	46.11	83.19	0.00
Decontamination & decommissioning	0.00	0.00	0.00
TOTAL	49.61	86.69	0.00

Table 6.13 Cost Breakdown (in Millions of Dollars) for Preparing Nonconforming Cylinders - Overcontainer Option

	Reference	Low	High
Engineering Technology	0.82	0.82	0.82
Inspection and retrieval equipment			
Engineering	0.23	0.23	0.23
Fabrication	1.93	1.93	1.93
Certification	0.09	0.09	0.09
Subtotal	2.25	2.25	2.25
Overcontainers			
Engineering	0.54	0.28	0.86
Fabrication	2.39	1.22	3.80
Certification	0.15	0.08	0.24
Subtotal	3.08	1.58	4.90
Handling fixtures			
Engineering	0.06	0.06	0.06
Fabrication	0.47	0.47	0.47
Certification	0.02	0.02	0.02
Subtotal	0.55	0.55	0.55
Shipping fixtures			
Engineering	0.03	0.03	0.03
Fabrication	0.24	0.24	0.24
Certification	0.01	0.01	0.01
Subtotal	0.28	0.28	0.28
Facilities			
Engineering	0.00	0.00	0.00
Construction	0.00	0.00	0.00
Project management	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00
Regulatory compliance	1.13	1.13	1.13
Operations and maintenance			
Materials	6.60	5.88	7.47
Utilities	0.03	0.03	0.03
Labor	96.03	48.02	153.36
Waste Management & Disposal	0.33	0.33	0.33
Subtotal	102.99	54.26	161.19
Decontamination & decommissioning	0.00	0.00	0.00
TOTAL	111.10	60.87	171.12

Table 6.14 Cost Breakdown (in Millions of Dollars) for Preparing Nonconforming Cylinders - Transfer Facility Option

	Reference	Low	High
Engineering Development	2.46	2.46	2.46
Process Equipment			
Engineering	3.70	2.20	5.49
Fabrications	8.01	4.61	12.08
Installation	5.24	3.27	7.59
Certification & Test	0.35	0.20	0.53
Subtotal	17.30	10.28	25.69
Process Facilities			
Engineering	16.86	13.76	20.55
Construction	49.04	40.03	59.79
Proj. Management	10.97	8.96	13.38
Subtotal	76.87	62.75	93.72
Balance of Plant			
Engineering	12.46	10.72	14.55
Construction	36.26	31.18	42.32
Proj. Management	8.11	6.98	9.47
Subtotal	56.83	48.88	66.34
Regulatory Compliance	56.20	56.20	56.20
Operations and Maintenance			
Material	82.78	58.75	111.46
Utilities	28.17	25.46	31.41
Labor	278.51	251.68	310.53
Waste Management & Disposal	4.70	4.17	5.33
Subtotal	394.16	340.06	458.73
Decont. & Decom.	2.71	2.19	3.33
TOTAL	606.53	522.82	706.47

6.2.2 Process and Facility Uncertainties

Uncertainties in facility and process scope cover those factors that are usually beyond the contractor's or the architect/engineer's control or outside the scope of the original design, schedule, and cost estimate. The project owner (e.g., DOE) must have funds available to cover the cost effects of these factors, or allocate the process development and demonstration time and funds up front to reduce these uncertainties.

Cost impacts were estimated for various equipment additions and enhancements to address potential performance risks. It was assumed that equipment additions would mitigate possible throughput deficiencies or product/by-product quality issues. The reader is referred to Chapter 3 of the *Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride*, Rev. 2.

For the transfer facility and selected conversion facilities, the potential increase in the process equipment costs and the resulting increase in the associated process facility costs were estimated. Table 6.15 lists the facility cases addressed, summarizes the equipment sensitivity cases evaluated, and for these provides the sum of the process equipment and process facility cost increases relative to the same for the reference case cost (no performance risks) tabulated in previous sections. The impacts on balance of plant and operations and maintenance costs were not estimated.

Table 6.15 Performance Risks

Facility	Equipment Additions	% Cost Increase*
Cylinder Transfer	Double no. autoclaves	37
U_3O_8 Conversion: AHF	Double no. defluorination lines; enhance distillation system	16
U_3O_8 Conversion: HF Neutralization	Double no. defluorination lines	14
UO_2 Conversion: AHF	Double no. defluorination lines; enhance distillation system; double no. sintering furnaces	24
UO_2 Conversion: HF Neutralization	Double no. defluorination lines; double no. sintering furnaces	23
U-Metal Conversion: Batch	Double no. UF_6 to UF_4 reactors; double no. leach stages	6
U-Metal Conversion: Continuous	Double no. UF_6 to UF_4 reactors; Double no. UF_4 to U lines; add leach system	29

* Total increase in process equipment and process facility costs (balance of plant impacts not evaluated)

Autoclave transfer of UF_6 is a well-established technology. The comparatively high cost risk assigned to the cylinder transfer facility reflects the unavailability of precise heat transfer data for air-heated autoclaves. Air-heated autoclaves were used in the engineering analysis for the transfer facility due to the assumed condition of the cylinders being transferred and the increased likelihood that a cylinder would breach.

For all oxide conversion cases, there are engineering scaling uncertainties, including residency times, associated with the reactors (kilns) for converting UF_6 to oxide powder (U_3O_8 and UO_2). For the oxide conversion cases in which anhydrous hydrogen fluoride is produced, there is a small likelihood that there would be an unacceptable level of uranium

contaminant carryover into the distillation system. Therefore, the reference distillation system was modified to an extractive distillation system using sulfuric acid addition. Finally, for conversion to densified UO_2, there is engineering uncertainty associated with the scaling of the high-temperature sintering furnaces.

The batch metallothermic reduction to uranium metal is a well-established industrial technology. The estimated cost risk reflects (1) the scaling associated with the use of higher throughput tower reactors for the conversion of the UF_6 to the process feed (UF_4), and (2) the possibility that added leaching capacity would be required for the by-product (MgF_2) decontamination for its disposal as a nonhazardous solid waste.

The continuous metallothermic reduction to uranium metal is not an industrial process and requires extensive engineering development and testing. The assigned performance risk reflects the following: (1) the scaling associated with the use of higher throughput tower reactors, as in the case of the batch process, (2) the engineering uncertainties associated with the scaling of the reduction reactors and continuous casters, and (3) the significant possibility that a leaching system would be required to decontaminate the by-product (MgF_2) for its disposal as a nonhazardous solid waste.

6.3 Process Vulnerabilities

This section describes the vulnerability of the oxide conversion process producing CaF_2 and the metal conversion processes producing MgF_2 to changes in disposal requirements.

6.3.1 Disposal of CaF_2 By-product from HF Neutralization Options

As stated in Section 4.2.2, all of the conversion options produce potentially salable by-products—either AHF or CaF_2. Defluorination with AHF production is superior to defluorination with HF neutralization in terms of by-product value and waste avoidance. In the unlikely event that the recovered AHF could not be sold (because of the small [<1 ppm] uranium concentration), the concentrated HF would be neutralized with lime (CaO) to form about 18,600 MT (13,895 cubic yards) of CaF_2. In the absence of regulatory constraints regarding the uranium content, the CaF_2 could be sold as a feedstock for the commercial production of AHF.

If neither the AHF nor the CaF_2 could be sold, then the CaF_2 is assumed to be disposed of as nonhazardous solid waste. This case would result in a large waste stream (approximately 1 kg waste per kg uranium) that would bound the waste for defluorination (U_3O_8 or UO_2). The relatively small amounts of CaF_2 which are produced by the conversion options without neutralization are not considered in this vulnerability analysis. Neutralization of the AHF with lime (CaO) to form CaF_2 is also a reasonable variation for the metal conversion options and the gelation options. However, the impact of adding a neutralization step to the metal and gelation conversion options has not been quantified from either an engineering or a cost perspective.

A potential vulnerability is that disposal as low-level waste (LLW) would be necessary because of the small uranium content in the CaF_2, and the disposal costs would rise significantly. The pessimistic case then assumes that the by-product must be disposed as a LLW. The cost impacts of CaF_2 disposal are summarized in Table 6.16. Assumed disposal costs are \$2/ft^3 for nonhazardous solid waste and \$100/ft^3 for LLW, as defined in Section 3.2.8.

Table 6.16 Cost Impacts of Disposal of CaF_2 Resulting from Conversion Options with HF Neutralization (Millions of Dollars)

Option	CaF_2 (MT/yr.)	Cost of Disposal as Nonhazardous Solid Waste	Cost of Disposal as LLW	Total Conversion Cost*
U_3O_8 w/HF Neutralization	18,600	\$0.75/yr. (\$15 total)	\$38/yr. (\$750 total)	\$340 (Nonhazardous) \$544 (LLW)
UO_2 w/HF Neutralization	18,600	\$0.75/yr. (\$15 total)	\$38/yr. (\$750 total)	\$409 (Nonhazardous) \$614 (LLW)

* Discounted costs (7% p.a. rate). See Table 4.8 for reference cases involving sale of CaF_2.

The neutralization reference cases have total conversion costs of \$325M and \$395M for U_3O_8 and UO_2, respectively; therefore, CaF_2 disposal as a nonhazardous solid waste would result in a minor cost increase relative to its sale. However, CaF_2 disposal as a LLW would result in a major cost increase relative to its sale or disposal as a nonhazardous solid waste.

6.3.2 LLW Disposal of MgF_2 By-product from Metal Conversion Options

The metal conversion process produces MgF_2 in substantial quantities (about 10^4 MT or slightly under 8,000 cubic yards annually) which must be disposed as a waste. The batch metallothermic process includes a decontamination step for the MgF_2 by-product, resulting in < 90 ppm uranium. The by-product from the continuous metallothermic process is assumed to have a low enough uranium concentration (< 90 ppm) that decontamination would not be necessary. For both cases, it is assumed that the MgF_2 would be granted a free release exemption for disposal as a nonhazardous solid waste. This is the assumption for all the cost estimates in Chapters 4 and 5.

Exemptions for decontaminated MgF_2 have been granted, but the quantities were substantially smaller. The practical limitations on MgF_2 decontamination are presently unknown, but it is likely that the residual levels of uranium will be at least 10-fold greater than the levels in CaF_2 from the HF neutralization options (Section 6.3.1). Accordingly, and in the absence of a *de minimus* value, MgF_2 is judged to be more vulnerable for disposal as a LLW than CaF_2. The cost impacts for MgF_2 disposal are summarized in Table 6.17. Assumed disposal costs are \$2/ft^3 for nonhazardous solid waste and \$100/ft^3 for LLW, as defined in Section 3.2.8.

Table 6.17 Cost Impacts of Disposal of MgF_2 Resulting from Metal Conversion Options (Millions of Dollars)

Option	MgF_2 (MT/yr) ***	Cost of Disposal as Nonhazardous Waste (Reference Case)	Cost of Disposal as LLW	Total Conversion Cost*	Cost Increase for Disposal as LLW
Batch metallothermic reduction	9,663	$0.41/yr ($8.3 total)	$20.7/yr ($413 total)	$665 (Nonhazardous) $745 (LLW)**	$80
Continuous metallothermic reduction	10,097	$0.43/yr ($8.6 total)	$21.6/yr ($431 total)	$492 (Nonhazardous) $600 (LLW)	$108

* Discounted costs (7% p.a. rate). See Table 4.8 for reference cases.

** Takes into account increase in nongrouted MgF_2

*** Ungrouted weight.

Disposal as a LLW would result in a major increase in the metal conversion costs. The reference case assumes disposal as nonhazardous waste in bulk form. If grouting were required, there would be additional costs for the grouting operation and the increased disposal volume. In moving from the reference case to the LLW disposal case, the increase in option cost is less for the batch than for the continuous process. This is primarily due to the elimination of the decontamination system for the batch process. This reduces capital costs (process equipment and process facility) and eliminates the operations and maintenance cost associated with the decontamination system.

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ATTACHMENT 2

Louisiana Energy Services
Response to April 19, 2004
Request for Additional Information D-4

Uranium Disposition Services
"DUF6 Contract"
(DE-AC05-02OR22717)
(redacted copy)

DUF6 CONTRACT

WITH

URANIUM DISPOSITION SERVICES

[Redacted Copy]
8-29-02

SECTION B
SUPPLIES OR SERVICES AND PRICES/COSTS

B.1 ITEMS BEING ACQUIRED

(a) The Contractor shall furnish all personnel, facilities, equipment, material, supplies, and services (except as may be expressly set forth in this contract as furnished by the Government) and otherwise do all things necessary for, or incident to, the performance of the Statement of Work in Section C.

(b) Reports shall be prepared and submitted in accordance with Section J, Attachment M, Reporting Requirements Checklist, other clauses in the contract which specify reporting requirements, and other directions from the Contracting Officer or designee. The content of the specified plans and reports shall be in accordance with DOE Order 1332.1A, "Uniform Reporting System". The Contractor shall employ a project management reporting system which utilizes an integrated, resource-loaded, earned value planning and reporting system to produce formats consistent with the above content. The level of detail the Contractor provides in the plans and reports shall be commensurate with the scope and complexity of the task and the reporting categories delineated in Block 4, Planning and Reporting Requirements, and Block 6, Special Instructions, on the Reporting Requirements Checklist, or in a particular clause. The Contractor shall be responsible for levying appropriate reporting requirements on any subcontractors in such a manner as to ensure an integrated, bottom-to-top planning and reporting system which will meet the Contractor's reporting requirements to DOE.

[End of Clause]

B.2 ESTIMATED COST

All costs presented in this section exclude fee and exclude proceeds from the sale of recycled products.

The total estimated cost for the performance of the work under the contract is $495,575,799*. This total amount consists of the following components:

(a) The total estimated cost for design of two conversion facilities, including system requirements, permitting, project management, conceptual, preliminary, and final design, is $27,988,709.

* does not include any off-set credit for HF sales

(b) The total estimated cost for construction of the facility at Paducah, KY including site preparation, structures, equipment, pre-operational testing, operational readiness reviews, and project management is $93,955,874.

(c) The total estimated cost for construction of the facility at Portsmouth, OH including site preparation, structures, equipment, pre-operational testing, operational readiness reviews, and project management is $90,401,868.

(d) The total estimated cost for operations including cylinder management, waste/end product preparation/packaging, transportation, disposition, and project management is $283,229,348*.

[End of Clause]

B.3 FIXED FEE - DESIGN

A fixed fee of $2,379,040 shall be paid to the Contractor for performance of the design work under B.2 (a) above. There shall be no adjustment in the amount of the fee by reason of differences between any estimate of cost for performance of the work under this contract and the actual costs for performance of that work. Fee is subject to adjustment only under the provisions of the clause in Section I entitled, "Changes." The fixed fee payable under this contract shall become due and payable in monthly installments as approved by the Contracting Officer and in accordance with the clause in Section I entitled "Fixed Fee." The fixed fee shall be applicable to the prime contractor and its members in a joint venture or limited liability company, teaming partner, and subcontractors identified and considered a part of the selection and award of this contract, if any.

[End of Clause]

B.4 INCENTIVE FEE - CONSTRUCTION

(a) An incentive fee shall be paid to the Contractor for performance of construction work under B.2 (b) and (c) above in accordance with this clause and the clause entitled "Incentive Fee" in Section I. The target cost, target fee, minimum fee, maximum fee, and cost share ratio are shown below:

(1) Paducah, KY Facility

Target Cost $93,955,874

* does not include any off-set credit for HF sales

Target Fee $ 6,576,911

Minimum Fee $ 1,879,117

Maximum Fee $ 9,395,587

Cost Share Ratio Government/Contractor: 80 / 20

(2) Portsmouth, OH Facility

Target Cost $ 90,401,868

Target Fee $ 6,328,131

Minimum Fee $ 1,808,037

Maximum Fee $ 9,040,187

Cost Share Ratio: Government/Contractor 80 / 20

(b) The target fee shall be paid to the Contractor if the actual cost of construction is within the range of 95-105% of the target cost. If the actual cost of construction is less than 95% of the target cost, the Contractor will earn fee in addition to the target fee in accordance with the cost share ratio up to the maximum fee. If the actual cost of construction is greater than 105% of the target cost, the Contractor will earn less than the target fee in accordance with the cost share ratio, but no less than the minimum fee. Fee increased or decreased from the target fee begins when the cost is lower than 95% or when the cost exceeds 105%, i.e., one dollar below the 95% level is the first point that the Contractor earns additional fee based on the Contractor's share ratio in paragraph (a) for that one dollar, and conversely for one dollar above the 105% level

(c) In addition to an incentive fee for cost performance, an incentive fee shall be paid the Contractor for accelerating the scheduled completion date for construction specified in Section F. For every month (30 calendar days) in which the completion date is accelerated, the Contractor shall earn an additional incentive fee amount of 2% of the fee earned for cost performance not to exceed 10% of the fee earned for cost performance. For every month (30 calendar days) in which the completion date is delayed beyond the scheduled completion date in Section F, the Contractor's earned fee under cost performance shall be reduced by 2% not to exceed 10% of the earned fee for cost performance.

(d) Any changes to the target cost, schedule, or fees shall only be made in accordance with the clause entitled "Changes" in Section I.

(e) The Contractor will be paid a quarterly provisional fee during the period of construction as approved by the Contracting Officer consistent with the provisions of the clause entitled "Incentive Fee" in Section I, but subject to the retained amount specified in (g) below. Such payments shall be based on the target fee; the Contractor's progress toward completion of the construction effort in consideration of cost, schedule, and performance requirements; and subject to a 25% retainage.

(f) The incentive fee earned shall be applicable to the prime contractor and its members in a joint venture or limited liability company, teaming partner, and subcontractors identified and considered a part of the selection and award of this contract, if any.

(g) Upon successful completion of the construction effort in accordance with the contract requirements, the Contracting Officer shall determine the total fee earned by the Contractor consistent with the Section I clauses entitled, "Incentive Fee" and "Conditional Payment of Fee, Profit, or Incentives." If the amount of the total fee earned is less than the total amount of all provisional fee payments to date previously made to the Contractor, the Contractor shall reimburse DOE the difference including the retained fee amount of 25%. If the amount of total fee earned is more than the total amount of all prior payments previously made to the Contractor, DOE shall pay the Contractor the difference up to 75% of the total fee earned. The fee retained (25%) for construction of the Portsmouth facility shall be paid to the Contractor upon successful conversion at the Portsmouth facility of 6,750,000 kg of DUF_6. The fee retained (25%) for construction of the Paducah facility shall be paid to the Contractor upon successful conversion at the Paducah facility of 9,000,000 kg of DUF_6.

[End of Clause]

B.5 AWARD FEE - OPERATIONS AND CYLINDER MANAGEMENT

(a) An award fee shall be paid to the Contractor for performance of operations and cylinder management under B.2 (d) above in accordance with the provisions of this clause. The maximum available fee is $ 42,484,402 (however, the maximum available award fee shall not exceed 15% of the cost of operations in B.2(d)). The amount $ 8,496,880 (20% of the maximum available fee above) shall be available for award fee criteria addressed in paragraph (e) and $ 33,987,522 (80% of the maximum available fee above) shall be available for performance based incentives specified in paragraph (f).

(b) There shall be no adjustment in the amount of the maximum available fee by reason of differences between any estimate of cost for performance of the work under this contract and the actual costs for performance of that work. The fee is subject to adjustment only under the provisions of the clause in Section I entitled, "Changes".

(c) The Contractor may be paid quarterly provisional fee as approved by the Contracting Officer and consistent with demonstrated progress toward accomplishment of requirements specified in the Performance Evaluation and Measurement Plan(s) in paragraph (i) below. The Contractor shall promptly refund to the Government any amount of provisional fee paid that exceeds the amount of fee actually earned.

(d) The fee earned shall be applicable to the prime contractor and its members in a joint venture or limited liability company, teaming partner, and subcontractors identified and considered a part of the selection and award of this contract, if any.

(e) Award Fee Criteria

(1) Prior to the beginning of each evaluation period (by fiscal year or a shorter period if the first evaluation period begins within a fiscal year) under this contract for which operations or cylinder management is performed, the Contracting Officer shall unilaterally allocate, from the 20% portion of the maximum available fee in paragraph (a) above, the amount of available fee for the evaluation period.

(2) The available fee for the evaluation period determined in (e) (1) above shall be allocated to objective and/or subjective criteria unilaterally established by the Contracting Officer prior to the beginning of each evaluation period.

(3) The Contracting Officer shall modify the contract to reflect the total available fee for each evaluation period. The evaluation areas and individual requirements that are subject to the fee incentive shall be determined in accordance with paragraph (i) below. The evaluation periods shall be on a fiscal year basis unless a different period is mutually agreed to between the parties.

(f) Performance Based Incentives

(1) Cost-per-Kilogram - The maximum available fee for the cost-per-kilogram of DUF_6 processed and accepted by the disposition site shall be $ 21,242,201 (50% of the total maximum available fee in paragraph (a) of this clause). The cost-per-kilogram, target fee, minimum fee, maximum fee, and fee-earning-ratio for each evaluation period is shown below:

(i)

Table 1. Cost-per-Kilogram - Incentive Table						
Evaluation Period	Target Cost per Kg	Target Fee	Cost/Kg for Minimum Fee	Minimum Fee	Cost/Kg for Maximum Fee	Maximum Fee
FY2005 (Aug->Sep)	$ 20.08	$1,379,370	$ 25.10	$ 551,748	$ 18.07	$ 1,655,244
FY2006 (Oct->Sep)	$ 1.81	$3,518,834	$ 2.26	$ 1,407,534	$ 1.63	$ 4,222,600
FY2007 (Oct->Sep)	$ 1.61	$3,537,809	$ 2.01	$ 1,415,124	$ 1.45	$ 4,245,371
FY2008 (Oct->Sep)	$ 1.50	$3,325,346	$ 1.88	$ 1,330,139	$ 1.35	$ 3,990,416
FY2009 (Oct->Sep)	$ 1.46	$3,239,240	$ 1.83	$ 1,295,696	$ 1.31	$ 3,887,088
FY2010 (Oct->Jul)	$ 1.46	$2,701,235	$ 1.83	$ 1,080,494	$ 1.31	$ 3,241,482

Notes to Table 1:

1) FY2005 and FY2010 represent 2 months and 10 months of operations, respectively.
2) Cost/Kg -Proposed change from Target cost: These percentages represent the amount the operating costs would have to change in order to achieve the minimum or maximum fee proposed. Any cost adjustment between the target and these minimum and maximum values would be linear. Example: If a 10% decrease in costs would increase the potential award from 6% to 7.5%, then 5% decrease in costs would result in a potential award of 6.75%.
3) Fee calculations are based on total proposed costs. Target, minimum, and maximum costs per kg exclude tipping costs.

(ii) The fee payable under this incentive, (f)(1), shall be the target fee for each evaluation period listed in the Cost-per-Kilogram - Incentive Table in paragraph (f) (1) (i) above (1) increased by (see Table 2) dollar(s) for every cent that the allowable cost-per-kilogram is less than the target cost-per-kilogram for each evaluation period listed in the Cost-per-Kilogram - Incentive Table in paragraph (f) (1)(i) above or (2) decreased by (see Table 3) dollar(s) for every cent that the allowable cost-per-kilogram exceeds the target cost-per-kilogram for each evaluation period listed in the Cost-per-Kilogram - Incentive Table in paragraph (f)(1)(i). In no event shall the fee in a given evaluation period for the cost-per-kilogram incentive be greater than the maximum fee or less than the minimum fee listed for each evaluation period in the Cost-per-Kilogram-Incentive Table in (f)(1)(i).

Table 2. Fee Adjustment If Actual Cost Is Less Than Target Cost/Kg			
Evaluation Period	Maximum Fee - Target Fee	Change In Cost/Kg	Fee Increase per $.01 Change In Cost/Kg
FY2005 (Aug->Sep)	$ 275,874	$ 2.01	$ 1,372,510
FY2006 (Oct->Sep)	$ 703,767	$ 0.18	$ 39,098
FY2007 (Oct->Sep)	$ 707,562	$ 0.16	$ 44,223
FY2008 (Oct->Sep)	$ 665,069	$ 0.15	$ 44,338
FY2009 (Oct->Sep)	$ 647,848	$ 0.15	$ 43,190
FY2010 (Oct->Jul)	$ 540,247	$ 0.15	$ 36,016

Notes to Table 2:
1) FY2005 and FY2010 represent 2 months and 10 months of operations, respectively.
2) Cost/Kg - Proposed change from Target cost: These percentages represent the amount the operating costs would have to change in order to achieve the minimum or maximum fee proposed. Any cost adjustment between the target and these minimum and maximum values would be linear. Example: If a 10% decrease in costs would increase the potential award from 6% to 7.5%, then a 5% decrease in costs would result in a potential award of 6.75%.

Table 3. Fee Adjustment If Actual Cost Is Exceeds The Target Cost/Kg			
Evaluation Period	Maximum Fee - Target Fee	Change In Cost/Kg	Fee Decrease per $.01 Change In Cost/Kg
FY2005 (Aug->Sep)	$ 827,622	$ 5.02	$ 1,649
FY2006 (Oct->Sep)	$ 2,111,300	$ 0.45	$ 46,918
FY2007 (Oct->Sep)	$ 2,122,686	$ 0.40	$ 53,067
FY2008 (Oct->Sep)	$ 1,995,208	$ 0.38	$ 52,505
FY2009 (Oct->Sep)	$ 1,943,544	$ 0.37	$ 52,528
FY2010 (Oct->Jul)	$ 1,620,741	$ 0.37	$ 43,804

Notes to Table 3:
1) FY2005 and FY2010 represent 2 months and 10 months of operations, respectively.
2) Cost/Kg - Proposed change from Target cost: These percentages represent the amount the operating costs would have to change in order to achieve the minimum or maximum fee proposed. Any cost adjustment between the target and these minimum and maximum values would be linear. Example: If a 10% decrease in costs would increase the potential award from 6% to 7.5%, then a 5% decrease in costs would result in a potential award of 6.75%.

(iii) For the purpose of establishing the cost-per-kilogram under this incentive only, the cost for each evaluation period shall be all allowable costs for operations and cylinder management in accordance with the clause I.20, Allowable Cost and Payment, except unallowable costs in accordance with paragraph (e)(4) of clause I.22, Incentive Fee, and excluding "tipping" cost at any waste disposal site(s). "Tipping costs," as used in this clause, shall mean those charges

levied by a disposal facility or facilities in exchange for the facilities' receipt for disposition of any products resulting from the conversion of DUF_6. Tipping costs do not include costs associated with any transportation required to deliver the materials to the facility or facilities for disposition. The cost-per-kilogram shall not be offset by revenues credited to the contract that were generated by the disposition of processing by-products or converted DUF_6 in accordance with clause H.32, "Sale of Product or By-Product". The number of kilograms processed, for incentive fee determination purposes, during each evaluation period, will be defined as (a) all DUF_6 processed and shipped off-site and accepted by a DOE-approved disposition site(s), as well as (b) any DUF_6 processed and/or shipped off-site during a previous evaluation period and not accepted by a DOE-approved disposition site during that period but accepted by a DOE-approved disposition site(s) during the current evaluation period. If for a reason beyond the control of the Contractor, any DUF_6 conversion product that meets the requirements of the DOE-approved disposition site(s) cannot be shipped off-site to the disposition site, then the number of kilograms of DUF_6 processed during the evaluation period and ready for shipment shall be used as the basis for this incentive. An equitable adjustment shall be made in the cost-per-kilogram solely to reduce the cost-per-kilogram by those costs included in the cost-per-kilogram associated with the transportation of the DUF_6 conversion product to the disposition site. In no case shall the same kilograms be included in the calculation of the total kilograms processed for more than one evaluation period.

(2) Number of Kilograms Processed: The maximum available fee for the number of kilograms processed and accepted by the disposition site shall be $8,496,880 (20% of the total maximum available fee in paragraph (a) of this clause). The number of kilograms processed, target fee, minimum number of kilograms fee, maximum fee, and fee-earning-ratio for each evaluation period is shown below:

(i)

Table 4. Number of Kilograms Processed - Incentive Table						
Evaluation Period	Target No. Kg	Target Fee	Minimum No. of Kg	Minimum No. of Kg Fee	No. Kg for Maximum Fee	Maximum Fee
FY2005 (Aug->Sep)	1,050,000	$ 551,748	525,000	$ 220,699	1,837,000	$ 662,098
FY2006 (Oct->Sep)	27,825,000	$1,407,534	19,500,000	$ 563,013	31,237,000	$1,689,040
FY2007 (Oct->Sep)	31,500,000	$1,415,124	22,000,000	$ 566,049	35,300,000	$1,698,148
FY2008 (Oct->Sep)	31,500,000	$1,330,139	22,000,000	$ 532,055	35,300,000	$1,596,166
FY2009 (Oct->Sep)	31,500,000	$1,295,696	22,000,000	$ 518,278	35,300,000	$1,554,835
FY2010 (Oct->Jul)	26,250,000	$1,080,494	18,375,000	$ 432,198	29,416,667	$1,296,593

Notes to Table 4:
1) FY2005 and FY2010 represent 2 months and 10 months of operations, respectively.

(ii) The fee payable under this incentive, (f)(2), shall be the target fee for each evaluation period listed in the Number of Kilograms Processed - Incentive Table in paragraph (f) (2) (i) above (1) increased by (see Table 5) cents(s) for every kilogram actually processed in an evaluation period that exceeds the target kilograms for each evaluation period listed in the table described in (f)(2)(i) above or (2) decreased by (see Table 6) cent(s) for every kilogram actually processed that is less than the target number of kilograms for each evaluation period listed in the table described in (f)(2)(i) above. In no event shall the fee earned in an evaluation period for the number of kilogram's processed be greater than the maximum fee. No fee shall be earned under this incentive for each evaluation period if the minimum number of kilograms listed for each evaluation period in the table in (f)(2)(i) above is not processed and accepted by the disposition site during the evaluation period.

Table 5. Fee Adjustment If Actual Kgs Processed Exceeds Target					
Evaluation Period	Maximum Fee - Target Fee		Change In Kgs Processed	Fee Increase per Change In Kgs Processed	
FY2005 (Aug->Sep)	$	110,350	787,000	$	0.14
FY2006 (Oct->Sep)	$	281,507	3,412,000	$	0.08
FY2007 (Oct->Sep)	$	283,025	3,800,000	$	0.07
FY2008 (Oct->Sep)	$	266,028	3,800,000	$	0.07
FY2009 (Oct->Sep)	$	259,139	3,800,000	$	0.07
FY2010 (Oct->Jul)	$	216,099	3,166,667	$	0.07

Notes to Table 5:
FY2005 and FY2010 represent 2 months and 10 months of operations, respectively

Table 6. Fee Adjustment If Actual Kgs Processed Is Less Than Target					
Evaluation Period	Target Fee - Minimum Fee		Change In Kgs Processed	Fee Decrease per Change In Kgs Processed	
FY2005 (Aug->Sep)	$	331,049	525,000	$	0.63
FY2006 (Oct->Sep)	$	844,520	8,325,000	$	0.10
FY2007 (Oct->Sep)	$	849,074	9,500,000	$	0.09
FY2008 (Oct->Sep)	$	798,083	9,500,000	$	0.08
FY2009 (Oct->Sep)	$	777,418	9,500,000	$	0.08
FY2010 (Oct->Jul)	$	648,296	7,875,000	$	0.08

Notes to Table 6:
1) FY2005 and FY2010 represent 2 months and 10 months of operations, respectively

(iii) The number of kilograms processed, for incentive fee determination purposes, during each evaluation period, will be defined as (a) all DUF_6 processed and shipped off-site and accepted by a DOE-approved disposition site(s), as well as (b) any DUF_6 processed and/or shipped off-site during a previous evaluation period and not accepted by a DOE-approved disposition site during that period but accepted by a DOE-approved disposition site(s) during the current evaluation period. If for a reason beyond the control of the Contractor, any DUF_6 conversion product that meets the requirements of the DOE-approved disposition site(s) cannot be shipped off-site to the disposition site, then the number of kilograms of DUF_6 processed during the evaluation period and ready for shipment shall be used for this incentive. In no case shall the same kilograms be included in the calculation of the total kilograms processed for more than one evaluation period.

(3) Number ETTP Cylinders Shipped to Portsmouth, OH: The maximum available fee for the number of ETTP cylinders shipped to Portsmouth, OH on schedule shall be $ 2,124,220 (5% of the total maximum available fee in paragraph (a) of this clause). The allocation of this amount to each evaluation period shall be determined by the Contracting Officer prior to each evaluation period.

(i) The schedule and the number of cylinders to be shipped will be determined by the Contracting Officer prior to each evaluation period in accordance with this clause and be incorporated into the Performance Evaluation and Measurement Plan(s).

(ii) Award fee earned for each evaluation period shall be paid provisionally. Transportation of all ETTP cylinders to Portsmouth, OH shall be completed by December 31, 2009 in order to receive any fee otherwise earned for this evaluation area. If transportation of all ETTP cylinders to Portsmouth, OH, is not completed by December 31, 2009, the Contractor shall return all fee provisionally paid under this incentive.

(4) Fluorine Product Sales: The maximum available fee for fluorine product sales shall be $ 2,124,220 (5% of the total maximum available fee in paragraph (a) of this clause). The allocation of this amount to each evaluation period shall be determined by the Contracting Officer prior to each evaluation period. The quantity and target price of fluorine product sales will be determined by the Contracting Officer prior to each evaluation period in accordance with this clause and be incorporated into the Performance Evaluation and Measurement Plan(s). It is expected that the maximum revenues from fluorine product sales over the 5-year period of operation will be $ 24,688,125.

(g) All of the fee in paragraph (a) above shall be made available over the term of the contract to which this fee is applicable. Fee not earned during an evaluation period shall not be allocated to future evaluation periods, unless authorized by the Contracting Officer.

(h) Determination of Total Fee Earned.

(1) The Government shall, at the conclusion of each specified evaluation period, evaluate the Contractor's performance against the evaluation areas and individual requirements; and the Contracting Officer shall determine the total amount of fee earned. At the Contracting Officer's discretion, evaluation of incentivized performance may occur at the scheduled completion of specific incentivized requirements.

(2) The evaluation of the Contractor's performance shall be in accordance with the Performance Evaluation and Measurement Plan(s) described in paragraph (i) of this clause. The Contractor shall be promptly advised in writing of the fee determination, and the basis of the fee determination. In the event that the

Contractor's performance is considered to be less than the level of performance required by the Statement of Work or any other contract requirement, the Contracting Officer may, at his/her sole discretion, adjust the fee determination to reflect such performance in accordance with the clause entitled "Conditional Payment of Fee, Profit, or Incentives" in Section I.

(3) Schedule for fee Earned Determinations. The Contracting Officer shall issue a determination of the fee amount earned in accordance with the schedule set forth in the Performance Evaluation and Measurement Plan(s). However, a determination must be made within sixty calendar days after the receipt by the Contracting Officer of the Contractor's self-assessment, that is to be submitted in accordance with paragraph (j) below. If the Contracting Officer evaluates the Contractor's performance of specific requirements on their completion, the payment of any amount of earned fee must be made within sixty calendar days (or such other time period as mutually agreed to between the Contracting Officer and the Contractor) after such completion. If the determination is delayed beyond that date, specified above, the Contractor shall be entitled to interest on the determined total available fee amount earned at the rate established by the Secretary of the Treasury under section 12 of the Contract Disputes Act of 1978 (41 U.S.C.611) that is in effect on the payment date. This rate is referred to as the "Renegotiation Board Interest Rate," and is published in the Federal Register semiannually on or about January 1 and July 1. The interest on any late total available fee amount earned determination will accrue daily and be compounded in 30-day increments inclusive from the first day after the scheduled determination date through the actual date the determination is issued. That is, interest accrued at the end of any 30-day period will be added to the determined amount of fee earned and be subject to interest if not paid in the succeeding 30-day period. The period when the Contractor is entitled to interest will end when a determination is made of the amount of fee earned for that specific evaluation period. After determination of the amount of fee earned, the Contractor shall submit invoices in accordance with Clauses G. 2 Submission of Vouchers-Invoices and I. 20 52.216-7 Allowable Cost and Payment (MAR 2000) Alternate I (FEB 1997) Modified by DEAR 952.216-7 Alternate II, and payment of any fee earned shall be subject to Clause I.79 52.232-25 Prompt Payment (JUNE 1997).

(i) Performance Evaluation and Measurement Plan(s).

(1) The Government shall establish a Performance Evaluation and Measurement Plan(s) upon which the determination of the total available fee amount earned shall be based. A copy of the Performance Evaluation and Measurement Plan(s) shall be provided to the Contractor not later than thirty days prior to the scheduled start date of the evaluation period.

(2) The Performance Evaluation and Measurement Plan(s) will set forth the criteria upon which the Contractor will be evaluated relating to any technical, schedule, management, and/or cost objectives selected for evaluation. Such criteria should

be objective, but may also include subjective criteria. The Plan(s) shall also set forth the method by which the total available fee amount will be allocated and the amount earned determined. The Plan(s) shall include those performance based incentives previously established in (f)(1) and (f)(2) and those in (f)(3) and (f)(4) to be established prior to each evaluation period.

(3) The Performance Evaluation and Measurement Plan(s) may, consistent with the contract statement of work, be revised unilaterally by the Contracting Officer during the evaluation period, except for the performance based incentives specified in (f)(1) and (f)(2). The Contracting Officer shall notify the Contractor of such unilateral changes at least thirty calendar days prior to the effective date of the change and at least ninety calendar days prior to the end of the affected evaluation period unless the parties mutually agree otherwise.

(j) Contractor self-assessment.

(1) Following each evaluation period, the Contractor shall submit a self-assessment, within 60 calendar days after the end of the period. This self-assessment shall address both the strengths and weaknesses of the Contractor's performance during the evaluation period. Where deficiencies in performance are noted, the Contractor shall describe the actions planned or taken to correct such deficiencies and avoid their recurrence. The Contracting Officer will review the Contractor's self-assessment, as part of its independent evaluation of the Contractor's performance during the period. A self-assessment, in and of itself, may not be the only basis for the fee determination.

(2) For the performance incentives in paragraph (f) of this clause, the Contractor shall, within 60 days after the end of the applicable evaluation period, submit to the Contracting Officer the Contractor's actual performance under each incentive and data that supports the calculation of the actual incentive performance. This supporting data shall include the allowable cost in accordance with (f)(1), the number of kilograms processed and accepted by the disposition site in accordance with (f)(2), the number of ETTP cylinders shipped in accordance with (f)(3), and the quantity and price of fluorine product sales in accordance with (f)(4). The Contractor will certify that the data submitted to the Contracting Officer to support the Contractor's claimed incentive performance is accurate and complete.

(3) The Contracting Officer or his designee may review/audit the Contractor's supporting data and/or other relevant books, documents, records, etc. to verify the Contractors actual incentive performance. If such review/audit results in questioned costs and or fee earned, the Contracting Officer and the Contractor may attempt to reach a negotiated agreement as to fee earned. If a mutual agreement is not reached, the Contracting Officer may unilaterally determine the amount of fee earned. If the Contracting Officer subsequently determines that the fee paid is greater than fee earned, the Contractor shall reimburse DOE as directed by the Contracting Officer the difference plus interest at the rate

established by the Secretary of the Treasury under section 12 of the Contract Disputes Act.

[End of Clause]"

B.6 OBLIGATION OF FUNDS

The design, construction, operations and cylinder management work under the contract will be incrementally funded. The amount presently obligated by the Government to this contract in accordance with the clause entitled "Limitation of Funds" in Section I is $5,000,000. Such amount may be increased unilaterally by the Contracting Officer by written notice to the Contractor and may be increased or decreased during the performance period by written agreement of the parties (whether or not by formal modification of this contract). These funds are estimated to cover the period through February 28, 2003.

[End of Clause]

SECTION C

DESCRIPTION/SPECIFICATIONS/WORK STATEMENT

CONTENTS

SECTION C
STATEMENT OF WORK

I. Objective

The primary objective of this contract is to design, construct, and operate conversion facilities on DOE property at Paducah, Kentucky, and Portsmouth, Ohio. These facilities will convert DOE's inventory of depleted uranium hexafluoride (DUF_6) now located at the Paducah Gaseous Diffusion Plant, the Portsmouth Gaseous Diffusion Plant, and the East Tennessee Technology Park (ETTP) to triuranium octoxide (U_3O_8), uranium dioxide (UO_2), uranium tetrafluoride (UF_4), uranium metal, or some other stable chemical form acceptable for transportation, beneficial use/reuse, and/or disposal. Any conversion product form must have an assured, environmentally acceptable path for final disposition. A related objective is to provide cylinder surveillance and maintenance (S&M) of the DOE inventory of DUF_6, low-enrichment uranium (LEU) hexafluoride (UF_6), natural assay UF_6, and empty and heel cylinders in a safe and environmentally acceptable manner.

II. Background

A. History of Uranium Enrichment

1. DOE has the programmatic responsibility for the Government's DUF_6 inventory as the successor of the Atomic Energy Commission and the Energy Research and Development Administration.

2. DUF_6 results from the process of making uranium suitable for use as fuel for nuclear reactors or military applications. The use of uranium in these applications requires increasing the proportion of the ^{235}U isotope found in natural uranium, which is approximately 0.7%, through an isotopic separation process called uranium enrichment.

3. Gaseous diffusion was the enrichment process used to create this inventory. This process requires uranium in the form of UF_6, a chemical compound consisting of one atom of uranium combined with six atoms of fluorine. It can be a solid, a liquid, or a vapor, depending on its temperature and pressure. It is used for the gaseous diffusion process primarily because it can conveniently be used in the vapor form for processing, in the liquid form for filling or emptying containers or equipment, and in the solid form for storage and transportation. At atmospheric pressure UF_6 is a solid at temperatures below 134°F (57°C) and a vapor at temperatures above 134°F. Solid UF_6 is a white, dense, crystalline material that resembles rock salt.

4. In the gaseous diffusion process, a stream of heated UF_6 gas is separated into two parts: one enriched in ^{235}U and the other depleted in ^{235}U. The enriched UF_6 is used for manufacturing commercial reactor fuel, which typically contains 2–5%

^{235}U, or for military applications (e.g., naval reactor fuel), which requires further enrichment of ^{235}U. The DUF_6, which typically contains 0.2–0.4% ^{235}U, is stored as a solid in large metal cylinders at the gaseous diffusion facility.

5. Large-scale uranium enrichment in the United States began as part of atomic bomb development by the Manhattan Project during World War II. Uranium enrichment activities were subsequently continued under the U.S. Atomic Energy Commission and its successor agencies, including DOE. The K-25 Plant in Oak Ridge, Tennessee (now East Tennessee Technology Park, or ETTP), was the first of three gaseous diffusion plants constructed to produce enriched uranium; the other two plants are in Paducah, Kentucky, and Portsmouth, Ohio. The K-25 Plant ceased operations in 1985, but uranium enrichment continues at both the Paducah and Portsmouth sites. These two plants are now operated by the United States Enrichment Corporation (USEC), created by the Energy Policy Act of 1992, which led to privatization of the uranium enrichment program.

B. Storage and Disposition of Depleted Uranium

1. Since the 1950s, DUF_6 has been stored at Oak Ridge, Paducah, and Portsmouth in large steel cylinders. Several different cylinder types, including 137 nominal 19-ton cylinders (Paducah) made of former UF_6 gaseous diffusion conversion shells, are in use, although the vast majority of cylinders have a 14-ton (12-metric-ton) capacity. The cylinders are typically 12 ft (3.7 m) long by 4 ft (1.2 m) in diameter, with most having a wall thickness of 5/16 in. (0.79 cm) of steel. Similar but smaller cylinders are also in use. During storage, a cylinder contains solid DUF_6 in the bottom and DUF_6 gas at less than atmospheric pressure. The DUF_6 cylinders managed by DOE at the three sites are typically stacked two cylinders high in large areas called yards.

2. The chemical and physical characteristics of DUF_6 pose potential health risks, and the material is handled accordingly. Uranium and its decay products in DUF_6 in storage emit low levels of alpha, beta, gamma, and neutron radiation. The radiation levels measured on the outside surface of filled DUF_6 storage cylinders are typically about 2 to 3 millirem per hour (mrem/h), decreasing to about 1 mrem/h at a distance of 1 ft (0.3 m). If DUF_6 is released to the atmosphere, it reacts with water vapor in the air to form hydrogen fluoride (HF) and a uranium oxyfluoride compound called uranyl fluoride (UO_2F_2). These products are chemically toxic. Uranium is a heavy metal that, in addition to being radioactive, can have toxic chemical effects (primarily on the kidneys) if it enters the bloodstream by means of ingestion or inhalation. HF is an extremely corrosive gas that can damage the lungs and cause death if inhaled at high enough concentrations.

3. Cylinders are stored with minimum risks to workers, members of the general public, and the environment at the Paducah, Portsmouth, and ETTP sites. DOE maintains an active cylinder management program to improve storage conditions in the cylinder yards, to monitor cylinder integrity by conducting routine inspections for breaches, and to perform cylinder maintenance and repairs to cylinders and storage yards, as needed.

4. The Department has characterized the presence of transuranic and technetium contamination in the depleted UF_6 cylinders using existing process knowledge and additional sampling of cylinders. The results of this characterization show non-detectable or very low levels of transuranics dispersed in the depleted UF_6 stored in the cylinders. However, there are higher levels of transuranics associated with "heels" remaining in a small number of cylinders formerly used as recycled uranium feed cylinders. The total quantities of transuranics and technetium contained in the entire inventory of depleted UF_6 fall within the DOE Category 3 nuclear facility quantities.

5. As the inventory of DUF_6 cylinders age, some cylinders have begun to show evidence of external corrosion. To date, ten cylinders have developed holes (breaches). However, since DUF_6 is a solid at ambient temperatures and pressures, it is not readily released from a cylinder following a leak or breach. When a cylinder is breached, moist air reacts with the exposed DUF_6 solid and iron, resulting in the formation of a dense plug of solid uranium and iron compounds and a small amount of HF gas. This plug limits the amount of material released from a breached cylinder. When a cylinder breach is identified, the cylinder is typically repaired or its contents are transferred to a new cylinder.

6. DOE has responsibility for continued management of the DUF_6 cylinders stored at the Paducah, Portsmouth, and ETTP sites. Since 1990, the Department's cylinder management has focused on the ongoing surveillance and maintenance (S&M) of the cylinders containing DUF_6, which involves cylinder inspections, recoatings, and relocations to ensure that DUF_6 is safely stored pending its ultimate disposition. Public Law (P.L.) 105-204, signed by the President in July 1998, directed the Secretary of Energy to prepare and submit to Congress a plan to ensure that all funds accrued on the books of USEC for the disposition of DUF_6 will be used for the construction and operation of plants to treat and recycle DUF_6 consistent with the National Environmental Policy Act (NEPA). The Department has responded to the law by initiating a procurement action through release of a Request for Expressions of Interest on March 4, 1999, and issuing the *Final Plan for the Conversion of Depleted Uranium Hexafluoride* in July 1999. This contract furthers the procurement action undertaken by DOE.

7. The Department's *Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride*, dated April 1999, described the preferred alternative for managing DUF_6. The Record of Decision (ROD) concerning the Department's

decision on the long-term management and use of DUF_6 was issued in August 1999.

C. Site Information

1. The Paducah Gaseous Diffusion Plant is located in western McCracken County, 15 miles west of Paducah, Kentucky, between U.S. Highway 60 and the Ohio River and consists of approximately 115 buildings and structures. One of these buildings, C-340, converted DUF_6 to UF_4 and UF_4 to uranium metal, circa 1953-1977. Building C-340 is not functional, is in a degraded condition, and is scheduled for decontamination and demolition. A single rail system serves the plant. DOE leases facilities required for the gaseous diffusion operation to USEC. That portion of the site leased to USEC is regulated by the Nuclear Regulatory Commission (NRC). The remainder of the site is managed by a DOE prime Contractor. There are and have been some additional third-party tenants leasing unused facilities. For a description of DOE owned Paducah cylinder yards relevant to this contract, see Section J, Attachment A, and Reference A. Although no site is selected until National Environmental Policy Act (NEPA) activities have been completed and a record of decision has been issued, the candidate site for the conversion plant is the flat grassy field between the main cylinder storage yard and the main road coming into the south end of the plant and adjacent wooded area. A map of the Paducah Plant, existing cylinder yards, and proposed conversion facility site, is provided in Reference B. Relevant site characterization information is provided in Section J, Attachment G. A portion of the candidate conversion facility site is designated a Solid Waste Management Unit (SWMU 194) in the Paducah Federal Facilities Agreement and is subject to evaluation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Contractor should assume the candidate site will be suitable for construction and operation under an industrial land-use scenario.

2. The Portsmouth Gaseous Diffusion Plant is located 23 miles north of Portsmouth near Piketon, Ohio, on U.S. Highway 23. A single rail system serves the plant. DOE leases facilities required for the gaseous diffusion operation to USEC. That portion of the site leased to USEC is regulated by NRC. The remainder of the site is managed by a DOE prime Contractor. There are and have been some additional third-party tenants leasing unused facilities. For a description of DOE owned Portsmouth cylinder yards relevant to this contract, see Section J, Attachment B, and Reference C. Although no site is selected until National Environmental Policy Act (NEPA) activities have been completed and a record of decision has been issued, the candidate site for the conversion plant is the lithium warehouse area, an area surrounding and including warehouses X-744S, T and U. The candidate conversion site, in general, is bounded on the west side by an unnamed road west of X-744T; on the north and east side by a truck access road; and on the east and south side by a dirt construction road. Excluded from this area are Buildings X-616 (USEC), X-106B, and X-106C

(USEC). A general map of the Portsmouth Plant, existing cylinder yards, and candidate conversion facility site is provided in Reference B. For information regarding relevant site characterization, see Section J, Attachment G.

3. The East Tennessee Technology Park (ETTP) is located within the city limits of Oak Ridge, Tennessee, on State Highway 58. The site is served by a single rail system. Commercial firms are located on the site as part of the ETTP reindustrialization activities. Several DOE prime Contractors are located on the site. A general map of ETTP and existing cylinder yards is provided in Reference B. For a description of DOE owned ETTP cylinder yards relevant to this contract, see Section J, Attachment C, and Reference D.

III. Project Management

A. Management

1. The Contractor shall ensure effective performance of all activities necessary to (a) produce the conceptual, preliminary, and final designs; (b) execute the construction; (c) operate the DUF_6 conversion facilities; and (d) carry out the cylinder management activities. The Contractor shall prepare a **Project Management Plan (PMP) (D-1)** for approval by the Contracting Officer or designee. The PMP will describe the purpose, scope, primary participants, and proposed methods of accomplishment. The Contractor shall comply with the approved PMP. Major elements of the PMP shall include the following:

   a) *Management Organization and Responsibilities.* Describe the functional organization charts depicting the project team. The significant project interfaces and lines of responsibility, authority, accountability, and communications should be identified and described. This section deals with how the organization will function—not just the administrative reporting lines. The principal responsibilities of the primary functional organizations should be delineated.

   b) *Work Plan.* Describe in detail how the work will be accomplished, including the use of subcontractors consistent with provisions in the clause entitled "Subcontracting Requirements" in Section H, through a project summary and a work breakdown structure (WBS) that reflects the key project elements. This WBS should provide the basis for the organization of work, cost estimating, and project tracking. Describe the systems to be used to manage, measure, plan, and control the costs of each portion of the contract.

   c) *Schedule.* Present in logic diagram format a project schedule keyed to the WBS. All efforts required to execute the project are to be reflected in the schedule, including, but not limited to design and construction activities, procurement, cylinder surveillance and maintenance, transportation of ETTP

cylinders to Portsmouth, disposition of heels and empty cylinder, conversion operation, and transportation and disposition of conversion products and wastes. The logic diagram will reflect the project's critical path and all major activities, milestones, key interfaces and decision points, and documents (environmental documentation, safety analysis, permitting, etc.).

d) *Configuration Management.* Describe the configuration management and control plans that shall be implemented at the inception of the project. These plans will include descriptions of the appropriate quality assurance elements, control boards, and methodology for managing the technical and cost aspects of the project. At a minimum, the following shall be required:

(1) Change thresholds and respective approval authorities will be established, and documented records will be maintained for proposed changes and actions.
(2) Changes to approved, but non-baseline data elements will also be done in a manner that maintains traceability.
(3) Configuration management will be applied only to those baseline data elements specifically identified as configuration items.

e) *Site Interfaces:* Describe how the Contractor will interface with USEC and other on-site Contractors for the provision of shared or purchased services, utilities, and equipment. Transition of the cylinder S&M activities from the incumbent prime Contractor to the Contractor shall be discussed.

f) *Monthly Cost Reports.* Describe the approaches and tools that will be used to maintain control of scope, cost, and schedule and to manage regulatory interfaces during the project lifetime. The Contractor shall meet the reporting requirements specified in Section B.

2. The Contractor shall support DOE in the performance of external and internal Independent Project Reviews (prior to the start of final design and prior to the start of construction), monthly project reviews, monthly program reviews, and any other reviews by HQ or other government entities, i.e., GAO, IG, etc., related to this project.

B. National Environmental Policy Act (NEPA)

1. DOE will prepare necessary NEPA documentation covering all activities described in the Statement of Work in compliance with 10 CFR 1021 and 40 CFR 1500-1508. Unless DOE specifically decides otherwise, DOE will not issue the notice-to-proceed on final design until NEPA review(s) (i.e., environmental impact statement(s)) are completed and a Record of Decision has been issued. DOE anticipates a duration of NEPA activities of 16 months from award of this contract.

2. The Contractor shall support the NEPA compliance activities of the DOE. The support will include, but may not be limited to, responding to questions from the NEPA compliance team, sending one or more representatives to the EIS public scoping meetings and draft EIS hearings, and providing updated data to the NEPA team at two intervals. The **Initial NEPA Data (D-2)**, after contract award, involves updating of the NEPA data provided in the Contractor's proposal. The **Updated NEPA Data (D-3)** involves updating the design and safety analysis data that had been provided to the NEPA team at the time the draft EIS was prepared. The updated data would be used in the preparation of the final EIS. In particular, the Contractor shall provide descriptions and the environmental releases for one or more accidents belonging to the following four frequency categories; less than 0.000001 per year, between 0.000001 and 0.0001 per year, between 0.0001 and 0.01 per year, and greater than 0.01 per year. The accidents designated in each frequency category should provide upper bound estimates on the quantities of radionuclides and other hazardous constituents released to the environment.

C. Regulatory Management

1. The Contractor shall be responsible for regulatory and permitting activities required by the contract. The Contractor shall submit for the approval of the Contracting Officer or designee a **Regulatory and Permitting Management Plan (D-4)** and shall provide updates to this plan, as needed. This plan shall describe the strategy for ensuring that the facilities are constructed and operated in accordance with applicable requirements as required by the clause entitled "Laws, Regulations, and DOE Directives" in Section I. The Contractor shall include in the plan a schedule of regulatory and permitting actions. The schedule shall identify major milestones and all critical actions that are necessary to ensure that all licenses and permits have been obtained.

2. The Contractor shall acknowledge the following requirements in the Regulatory and Permitting Management Plan:

   a) DOE entered into a Consent Order with the Department of Environment and Conservation of the State of Tennessee (Section J, Attachment D) with respect to the management of the UF_6 stored at the ETTP site. The Contractor shall comply with the requirements of the Consent Order dated February 8, 1999. In addition, at the request of DOE, the Contractor shall become a party-signatory to the Consent Order with the Department of Environment and Conservation of the State of Tennessee, prior to undertaking any cylinder-related activities at ETTP.

   b) DOE entered into an agreement with the Ohio EPA for the management of the depleted uranium stored at the Portsmouth site (Section J, Attachment E). This agreement, dated February 24, 1998, is entitled "Ohio EPA Director's Final Findings and Orders" (DFF&O). The DFF&O outlines the management, S&M activities, inspection requirements, and other requirements for the DUF_6 storage yards and cylinders owned by DOE at the Portsmouth site. The Contractor shall comply with the requirements of the

DFF&O. The Contractor shall become a party-signatory to the DFF&O prior to undertaking any cylinder-related activities covered by the DFF&O.

c) At the request of DOE, the Contractor shall negotiate in good faith and become a party-signatory to such future regulatory agreements or orders as DOE may deem appropriate for the work performed pursuant to this contract.

D. Quality Assurance

The Contractor is responsible for assuring that quality is integrated into all aspects of the work. The Contractor shall prepare a **Project Quality Assurance Plan (PQAP) (D-5)** for approval by the Contracting Officer or designee. The plan shall be developed and executed in accordance with 10 CFR 830.

E. Conversion Product Management

The Contractor is responsible for and shall perform all activities related to conversion products which are to be used/reused. These activities include product generation, transportation, storage, packaging, and disposition. The Contractor shall prepare and execute a **Conversion Product Management Plan (D-6)** for the management of all product generated for use/reuse. This plan shall describe how each identified product is generated and how it is to be managed from the point of generation to disposition. The plan shall include the quantities, methods, and timetables for the management of each product stream to be generated. The Conversion Product Management Plan shall be submitted to the Contracting Officer or designee for review and approval prior to the generation of any product. The plan shall be maintained and revised whenever changes are made that affect the management of product. All changes to the plan shall be subject to DOE approval by the Contracting Officer or designee.

F. Waste Management

The Contractor is responsible for and shall perform all activities related to waste management which include waste generation, transport, storage, treatment, waste minimization, waste certification, packaging, and disposal. The Contractor shall prepare a **Waste Management Plan (D-7)** for the management of wastes, that identifies all of the wastes to be generated. This plan shall describe how each identified waste is generated and how it is to be managed from the point of generation to disposal. The plan shall include the quantities, methods, and timetables for the management of each waste stream to be generated. The Waste Management Plan shall be submitted to the Contracting Officer or designee for review and approval prior to the generation of any wastes. The plan shall be maintained and revised whenever changes are made that affect the management of wastes. All changes to the plan shall be subject to DOE approval by the Contracting Officer or designee. The plan shall consider the management of radioactive waste, mixed waste, hazardous waste, and sanitary/industrial waste as outlined below.

a) For the management of radioactive waste and/or the radiological component of mixed waste generated by the project, the Contractor shall be subject to the

Contractor Requirements Document of DOE Order 435.1 (Attachment 1 to DOE Order 435.1). Under the requirements of this document, the Contractor shall systematically plan, document, execute, and evaluate the management of DOE radioactive waste and/or the radiological component of mixed waste in accordance with DOE Order 435.1 as required by the clause entitled "Laws, Regulations, and DOE Directives" in Section I. In so doing, the Contractor shall protect the public, the environment, and workers by maintaining exposures to radiation and radiological contamination as low as reasonably achievable.

b) The Contractor shall function as a generator of waste for the management of any hazardous, sanitary/industrial waste, or hazardous component of mixed waste associated with the proposed project. The responsibility for hazardous waste management, sanitary/industrial waste management, and hazardous component of mixed waste management rests with the Contractor. As the responsible party, the Contractor shall ensure that all hazardous and sanitary/industrial wastes, and hazardous components of mixed waste, are managed in compliance with the Resource Conservation and Recovery Act (RCRA) and with applicable regulations as required by the clause entitled "Laws, Regulations, and DOE Directives" in Section I.

G. Integrated Safety Management

1. Protection of workers, the public, and the environment are fundamental responsibilities of the Contractor and a critically important performance expectation. The Contractor's environment, safety and health (ES&H) program shall be operated as an integral, but visible, part of how the organization conducts business. A key element is implementing DOE Policy 450.4, "Safety Management System Policy," including prioritizing work planning and execution, establishing clear ES&H priorities, and allocating the appropriate level of trained and qualified resources to address programmatic and operational considerations. The Contractor shall ensure that cost reduction and efficiency efforts are fully compatible with ES&H performance.

2. The Contractor shall perform all activities in compliance with applicable health, safety, and environmental laws, orders, regulations, and national consensus standards; and governing agreements, permits, and orders executed with regulatory and oversight government organizations. The Contractor shall take necessary actions to preclude serious injuries and/or fatalities, keep worker exposures and environmental releases as low as reasonably achievable below established limits, minimize the generation of waste, and maintain or increase protection to the environment, and public and worker safety and health.

3. Incorporating integrated line management, the Contractor shall put in place a system that clearly communicates the roles, responsibilities, and authorities of line managers. The Contractor shall hold all line managers individually accountable for implementing necessary controls for safe performance of work in their respective areas of responsibility. The Contractor shall establish effective management systems to identify deficiencies, resolve them in a timely manner, ensure that corrective actions are implemented (addressing the extent of conditions, root causes, and measures to prevent recurrence), and prioritize and

track commitments and actions. The Contractor shall consider ES&H performance in selection of its subcontractors and incorporate ES&H requirements into subcontracts.

4. The Contractor shall develop and execute an **Integrated Safety Management System Plan (D-8)**. The plan shall be submitted to DOE for approval by the Contracting Officer or designee. The Contractor shall provide updates to this plan, as needed. The plan shall be prepared in accordance with the clause entitled "Integration of Environment, Safety, and Health into Work Planning and Execution" in Section I. Documentation of the plan shall describe how the Contractor will (1) define the scope of work; (2) identify and analyze hazards associated with the work; (3) develop and implement hazard controls; (4) perform work within controls; and (5) provide feedback on the adequacy of controls and continue to improve safety management. Prior to the development of this plan, the Contractor shall negotiate with the DOE the appropriate set of Work Smart Standards (WSS) and Standards/Requirements Identification Documents (S/RIDs). The plan shall identify proposed safety standards, describe why those safety standards were chosen, describe the implementation process for the proposed safety standards, demonstrate the administrative and management processes and infrastructure that support implementation of the proposed safety standards, and describe the approach to management of the regulatory process. The Contractor shall manage and perform work in accordance with this plan.

H. Radiation Protection

The Contractor shall be fully responsible for radiation protection and shall develop and execute a **Radiation Protection Plan (D-9)** in accordance with 10 CFR 835.

I. Security

The Contractor shall prepare and execute a **Site Security Plan (D-10)**. The Contractor shall provide updates to this plan, as needed. This document shall be a compendium of plans for meeting the DOE safeguards and security requirements. The plan shall include the Contractor's methodology for physical protection of the conversion facilities, information security, and personnel security. The Site Security Plan shall be prepared in accordance with the DOE Order 470 series requirements as they apply to the facilities that are planned as required by the clause entitled "Laws, Regulations, and DOE Directives" in Section I. The plan shall include protection of information from disclosure pursuant to Export Controlled Information (ECI) in accordance with 15 CFR 774 and Unclassified Controlled Nuclear Information (UCNI) requirements in 10 CFR 1017. The plan shall also include a sabotage vulnerability assessment covering all aspects of facility operation which might have an unacceptable impact on personnel, the public, or the environment. The Site Security Plan shall be coordinated with other on-site activities to ensure adequate protection of the conversion facilities and uranium-bearing materials. The DOE Contracting Officer or designee must approve the Site Security Plan.

J. **Material Safeguards**

The Contractor shall prepare and execute a **Nuclear Materials Control and Accountability Plan (D-11)** in accordance with DOE Order 474.1 and DOE Manuals 474.1-1 and 474.1-2 as required by the clause entitled "Laws, Regulations, and DOE Directives" in Section I. The Contractor shall provide updates to this plan, as needed. The plan shall include the Contractor's methodology for material control and accountability for uranium feed and conversion products. The DOE Contracting Officer or designee must approve the Nuclear Materials Control and Accountability Plan prior to the Contractor's assuming cylinder surveillance and maintenance responsibilities.

K. **Records Management**

The Contractor shall conduct records management in accordance with Title 44 USC, 36 CFR and other DOE requirements as directed by the Contracting Officer. The Contractor shall prepare a **Records Management Plan** (D-24) consistent with Clause I. 138, Access To and Ownership of Records. The plan will address all appropriate records issues delineated in the 'Roadmap to the Year 2000', DOE's records management program guidelines. The Roadmap is accessible through the DOE Chief Information Officer homepage at: http://cio.doe.gov. The records plan will clearly delineate records which are Government owned and which are Contractor owned. Final disposition of records (transfer to Federal Records Center, destruction, transfer to new contractor, etc.) will be addressed in the plan. The plan will be reviewed and approved by the Contracting Officer or designee.

IV. **Facility Planning**

A. **Design Bases**

1. Two conversion facilities shall be built, one at the Paducah Gaseous Diffusion Plant and one at the Portsmouth Gaseous Diffusion Plant, each producing the same depleted uranium product. Although no site is selected until National Environmental Policy Act (NEPA) activities have been completed and a record of decision has been issued, the candidate site at the Portsmouth Gaseous Diffusion Plant shall convert the DUF_6 inventory stored at that site and the DUF_6 inventory from the ETTP site, and the candidate site located at the Paducah Gaseous Diffusion Plant shall convert the DUF_6 inventory stored at the Paducah site. The conversion facilities shall be capable of processing safely DUF_6 cylinders, irrespective of size, shape, condition, and/or contents identified in the Cylinder Information Database (CID), Reference E, and in the Memorandum of Agreement Between the Department of Energy and the United States Enrichment Corporation, relating to depleted uranium, dated June 30, 1998 (Reference F), at a rate such that the total DUF_6 inventory at all three sites could reasonably be converted and dispositioned in no longer than 25 years after conversion operations start, subject to constraints of projected funding levels. Federal, state, and local codes in affect during the design period shall govern. Design shall incorporate aspects that will facilitate the efficient and economical decontamination, decommission, and demolition of the facilities. There is no requirement that identical designs be used for the two conversion plants;

however, the Contractor shall endeavor to take full advantage of the savings that can accrue from common procurement and construction actions, within the constraints of the varying regulatory requirements.

2. As a result of enrichment of recycled uranium in the early years of gaseous diffusion, some of the depleted UF_6 inventory is contaminated with small amounts of technetium and the transuranic elements plutonium, neptunium, and americium. Transuranic contamination in the UF_6 cylinders will exist as fluoride compounds that are both insoluble in liquid UF_6 and nonvolatile, but capable of being entrained from the cylinders during feeding of UF_6. The transuranic contamination will exist primarily as (1) small particulates more or less uniformly dispersed throughout the UF_6 contents, and (2) small quantities of consolidated residues ("heels") from the original feed stock to the cascades present in a relatively small but unknown number of cylinders. Technetium contamination will exist as fluoride and oxyfluoride compounds that are stable and partially volatile and will be present both uniformly dispersed throughout the UF_6 and in the "heels" material referred to previously.

3. The UF_6 contaminated with transuranic elements and technetium at the concentrations expected to be encountered can be safely handled. Table 1 shows values of the maximum expected concentrations of transuranic isotopes and technetium dispersed throughout the UF_6 in the storage cylinders. Table 2 shows values of the maximum expected concentration of transuranic and technetium contamination in nonvolatile residues ("heels") that are present in a small but unknown number of the cylinders. This "heels" material will remain in these cylinders after they are emptied.

Table 1. Bounding concentrations of dispersed transuranic and ^{99}Tc contamination in the DUF_6 tails cylinders

Contaminant	ppb_U
^{238}Pu	0.00012
^{239}Pu	0.043
^{237}Np	5.2
^{99}Tc	15.9
^{241}Am	0.0013

Table 2. Bounding concentrations of transuranic and ^{99}Tc contamination in DUF_6 feed heels material present in some cylinders

Contaminant	ppb_U
^{238}Pu	5
^{239}Pu	1,600
^{237}Np	54,000
^{99}Tc	5,700,000
^{241}Am	0.57

4. Table 3 shows values of the maximum expected total quantities of plutonium, neptunium, and technetium that can be contained in all of the depleted UF_6 inventory at all three sites.

Table 3: Maximum quantities of transuranics and technetium in DUF_6 inventory

Radionuclide	Grams
Pu	24
Np	17,800
Tc	804,000

5. The Contractor is responsible for any additional characterization necessary to support design activities.

B. System Requirements

The Contractor shall prepare and maintain a System Requirements Document (SRD) (D-12) to define the overall technical baseline of the project. The SRD shall be submitted to the DOE Contracting Officer or designee for approval. This document shall describe the input and feed materials; the processing steps; all products, and wastes to be generated by the facilities; the design life for the plant and specific primary components and systems; any known operational constraints; the production rates; and the operational basis (number of shifts, batch systems or continuous, etc.). The SRD draws on the information provided in the Contractor's proposal, and the requirements for the project schedule, cost, and method of accomplishment. The SRD is the technical reference base establishing and preserving the functional requirements, and it will be updated throughout the life of the project and provided to DOE for approval by the Contracting Officer or designee annually. A typical outline of the information included is as follows:

a) Mission Statement;
b) System Description (narrative and flow diagram);
c) Functional/Performance Requirements;
d) Interfaces;
e) Unique Project Constraints (process rate, cylinder transport);
f) Technical Uncertainties and Contingencies;
g) Permitting Requirements; and
h) Requirements Verification (those things needed to verify that requirements are met).

C. Conceptual Design

1. Conceptual design is the initial formal project design phase. The Contractor shall develop on a site-specific basis the initial engineering bases and design criteria

for a project design satisfying the functional requirements and performance criteria outlined in the SRD and design bases. Conceptual design activities are dedicated to:

a) Development of the design concept and basis for initiation of preliminary physical design,
b) Establishment of a project baseline, and
c) DOT certification of cylinder overpack design, if pursued.

Completion of the Conceptual Design will be documented using **Conceptual Design Report (CDR) Packages (D-13)**. The Contractor shall produce separate CDR packages for each facility (Portsmouth and Paducah) using the same format. The CDR shall include, but is not limited to, the project criteria and design parameters for all engineering disciplines, identification of applicable codes and standards, quality assurance requirements, environmental studies, materials of construction, space allowances, energy conservation features, health and safety, safeguards, and security requirements and any other features or requirements necessary to describe the project. The CDRs shall be organized to allow easy assessment of facilities, systems, hardware, components, operations, and maintenance. Additionally, the conversion facilities should be designed and built to provide the flexibility for future on-site neutralization of 100% of the HF product as a contingent strategy to allow continued DUF_6 conversion should the marketing of HF prove infeasible or be interrupted for any reason. General site arrangements and conversion buildings/processing equipment should be designed such that this future expansion may be accommodated with minimum reconfiguration of facilities and disruption to ongoing operations. Conceptual design for the possible future neutralization facilities shall be provided as a part of the Conceptual Design Report Packages (Deliverable D-13) to allow an appropriate footprint to be reserved for these facilities. For the 100% neutralization contingency, no further design or construction should be planned beyond conceptual design. The cost of the future neutralization facilities is not included in the estimated cost, other than minimal appropriate facility/utility allowances to provide for the future flexibility.

2. The Contractor shall fully explore conversion process and operations to validate the technical merit, define the operational characteristics and constraints, identify any remaining uncertainties and what steps shall be taken to eliminate those, and define the method of accomplishment for the remainder of the project. The Contractor shall submit information and support a full review of the conceptual design at approximately 30% and 80% completion (and other specific reviews as directed by DOE). These reviews shall include, but not be limited to, design, constructability, risk and vulnerability, regulatory compliance, and maintainability. The conceptual design packages shall consist of the CDR, a life cycle cost (LCC) estimate (detailed in the DOE Guidance Document GPG-FM-016, *Baseline Development*), and the following additional studies and information:

   a) Project schedule;
   b) Risk and vulnerability;

c) Maintainability and operability considerations;
d) Waste management plans and options;
e) Preliminary safety strategy, including a safety analysis report draft;
f) Preliminary discussion of design strategy for post-operational decontamination and decommissioning;
g) Value Engineering (VE) assessment;
h) Identification of applicable codes and standards;
i) Engineering subsystem trade studies (where appropriate); and
j) Process for obtaining DOT certified cylinder overpacks, if pursued.

3. The Life Cycle Cost estimate, expected to be accurate within 20%, shall include funding needs by fiscal year and an analysis of contingency to be applied.

4. Conceptual design is complete upon resolution and disposition of all DOE comments and the Contractor's issuance of the DOE-approved CDR Packages.

V. Design

A. Preliminary Design

1. The Contractor shall not begin Preliminary Design until the DOE Contracting Officer or designee issues a written notice-to-proceed. Based on the DOE-approved conceptual design, the Contractor shall complete development and preparation of a DUF_6 conversion facility preliminary design for each facility/site (Portsmouth and Paducah).

2. The preliminary design shall include, but not be limited to, the following: conduct of any trade-off studies, including evaluation of alternative designs; complete material (component) balances, including waste and by-product generations, disposal plans, estimates of fugitive emissions and releases; specifications, codes, and standards being applied to equipment and facilities; plant footprint, including land requirements and preliminary siting; identification of early, long-lead procurement items; equipment life design goals and expectations for major equipment items and process lines; special construction materials and planning for corrosion control; analyses of health, safety, and environmental protection; and critical path identification.

3. **Preliminary Design Packages (D-14)**, one for Portsmouth and one for Paducah, using similar formats, shall be prepared. These packages shall include complete bills of material; detailed equipment descriptions, specifications, and process conditions; material and energy balances; process and instrumentation diagrams; refinements of environmental considerations; and waste streams generated. The preliminary design packages shall also report on the status of site-specific permitting. The Contractor shall perform Value Engineering (VE) assessments; an evaluation to ensure that radiation exposures will be as low as reasonably achievable (ALARA analysis); reliability, availability, and maintainability (RAM) analysis; and a constructability review of the project. The safety analysis shall proceed concurrently with the design phase. Complete

reviews of all aspects of the project (including drafts of documents in progress) will be conducted by DOE. The preliminary design packages shall also include the following:

a) Outline operating procedures,
b) Drawing package of in-progress drawings,
c) Long-lead procurement listings,
d) Outline specifications,
e) Alternative analyses or engineering trade studies (in-progress),
f) Description of selected technology or process,
g) Updated codes and standards of record,
h) Updated waste estimates and disposal plans,
i) Updated cost estimate for the construction,
j) Updated schedule of design and construction,
k) Updated configuration management plans,
l) Updated System Requirements Document,
m) Preliminary safety analysis and assessments (PSAR),
n) Permitting update,
o) Utility requirements and acquisition plans,
p) Risks and vulnerabilities,
q) Environmental analyses, and
r) VE assessment.

4. Preliminary design is complete upon resolution and disposition of all DOE comments and the Contractor's issuance of the DOE-approved Preliminary Design Packages.

B. **Final Design**

1. The Contractor shall not begin Final Design until the DOE Contracting Officer or designee issues a written notice-to-proceed. Based on DOE approval of the Preliminary Design Packages by the Contracting Officer or designee, the Contractor shall complete preparation of the DUF_6 **Conversion Facility Design (Final Design) Packages (D-15)**. The Contractor shall produce separate packages of the design and analysis deliverables for each facility (Portsmouth and Paducah), but using the same format. These design packages shall include a description of the conditions, codes, and permits of record for both facilities. A VE study shall be performed at the beginning of final design. The Contractor will use the VE study to improve the approach already defined in the preliminary design packages. The Contractor shall develop independent design packages for the two sites; however, special attention should be paid to utilizing the same auxiliary analyses and evaluations for both sites and taking full advantage of economies of scale in construction and procurement planning. The Contractor shall arrange with DOE for full design reviews at approximately the 60% and 90% completion levels. These reviews shall include operability, constructability, environmental compliance and permitting, regulatory compliance, risk and vulnerability, hazard analysis and controls, bounding consequence analysis, maintainability, as well as all design outputs and documents prepared as part of

the final design effort. At a minimum, the design reviews shall be attended by representatives of the design, construction management, project management, and (planned) facility operations groups and will be conducted for DOE review and approval by the Contracting Officer or designee.

2. The final design packages shall include, but not be limited to, the following: an updated LCC estimate; complete, certified-for-construction design drawings, equipment specifications, data sheets, fabrication drawings, assembly information, and all other materials necessary to advance to the constructions stage; estimates of construction labor and material quantities; detailed estimates of construction and installation costs that are expected to be accurate within 10%; and procurement and construction schedules. This package will finalize the plant configuration and establish the basis for configuration management through the construction. The following shall also be included:

   a) Complete design drawing and specifications packages that are certified for construction;
   b) Detailed cost estimate for construction and testing;
   c) Detailed schedule through plant start-up;
   d) Surveillance plans for large procurement and vendor-supplied modules;
   e) Construction acceptance testing requirements and plans;
   f) Special procurement action listings and plans;
   g) Material receiving and tracking plans;
   h) Status of permitting for construction and operations;
   i) Outline operating procedures;
   j) Updated configuration management plans;
   k) Remaining technical analyses and uncertainties;
   l) Utilities requirements and acquisition plans; and
   m) VE study.

3. Final design is complete upon resolution and disposition of all DOE comments and the Contractor's issuance of the DOE-approved Final Design Packages.

C. Safety Analysis Reports

The Contractor shall prepare Safety Analysis Reports (SARs) that analyze the hazards of operations and identify mitigation strategies and systems to reduce to acceptable levels the potential for damage to equipment, personnel, the public, and the environment from both nuclear and non-nuclear hazards. Separate SARs shall be prepared for Paducah, Portsmouth, and ETTP. The requirements and guidance for the preparation of DOE SARs are detailed in, but may not be limited to the following: 10 CFR-830, DOE Order 5480.21, DOE Order 5480.22, DOE Order 5480.23, DOE Order 420.1, DOE Guide G420.1, DOE Order 440.1, DOE-STD-5502, DOE-STD-1120 through 1027, and DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports* and as required by the clause entitled "Laws, Regulations, and DOE Directives" in Section I. The SARs will document all hazards—including nuclear, chemical, and natural

phenomena hazards—and assess the impact of these events on safety. In this regard, nuclear and non-nuclear hazards shall be treated equally in the safety standards. Non-nuclear hazards shall be evaluated, documented, prevented, and mitigated in the same manner as the nuclear hazards: i.e., the DOE Order 5480.23 hazard class definition shall also apply to the non-nuclear hazards. **Preliminary Safety Analysis Reports (PSARs) (D-16)** shall be delivered at the completion of the preliminary design, at which time the documents will be reviewed by DOE. **Final Safety Analysis Reports (FSARs) (D-17)** shall be developed concurrently with the final design, and progress will be reviewed as part of the routine design reviews conducted by DOE. The Contractor shall provide updates to this plan, as needed.

VI. Cylinder Management

The Contractor shall not begin cylinder management until the DOE Contracting Officer or designee issues a written notice-to-proceed.

A. Transport of Cylinders from ETTP to Portsmouth

The Contractor shall prepare and execute a **Plan to Transport ETTP Cylinders to Portsmouth (D-18)** in accordance with DOT regulations, including obtaining all state and local permits as necessary. This plan is subject to DOE approval by the Contracting Officer or designee prior to execution.

The Plan shall describe the approach for shipment of cylinders of DUF_6, low-enrichment uranium (LEU) hexafluoride (UF_6), and natural assay UF_6 from ETTP to Portsmouth, as well as the disposition of heel and empty cylinders located at ETTP, by no later than December 31, 2009. This Plan shall include, but not limited to, the following elements:

1. Analysis of transportation options such as (a) obtaining a DOT exemption for nonconforming cylinders, (b) overpacking the cylinders, and (c) transferring of the contents of nonconforming cylinders to certified cylinders for transport;
2. Analysis of transportation modes (e.g., train, truck, barge) and routes for transport of ETTP cylinders to Portsmouth, Ohio;
3. Scheduling and estimation of the cost of transport for the various transportation options and modes;
4. Selection of the preferred transportation option and mode based upon cost effectiveness and safety; and
5. Identify any repairs to UF_6 packagings in accordance with ANSI-N14.1 that would be needed.

NOTE: If cylinder overpacks is the selected transportation option, the activities associated with DOT certification of the overpack design is included the design activities. Procurement of the necessary number of DOT certified overpacks and/or certified cylinders shall be included under cylinder management activities.

B. Cylinder Information Database (CID) Management

The Cylinder Information Database (CID) (Reference E) contains cylinder characterization, contents, inspection status, S&M activities, and location for the DOE-owned UF_6 inventory at the three sites. The Contractor shall maintain and update CID beginning on the date the Contractor assumes responsibility for cylinder management. The Contractor shall generate cylinder information or cylinder content reports as requested by DOE to support project and program requirements.

C. Three-Site Cylinder Surveillance and Maintenance

1. The Contractor shall perform surveillance and maintenance for the DOE inventory of DUF_6, low-enrichment uranium (LEU) hexafluoride (UF_6), natural assay UF_6, and heel and empty cylinders. DOE will transition management of cylinder S&M to the Contractor for integration into the conversion operations. Six months prior to the Contractor's assuming cylinder S&M activities, the Contractor shall submit to DOE a **Cylinder Surveillance and Maintenance Plan (D-19).** This plan must have DOE approval by the Contracting Officer or designee. The Contractor shall provide updates to this plan, as needed. This plan must be submitted and approved prior to the Contractor's assuming S&M responsibility and must address the requirements in the following documents:

   a) The *DOE Implementation Plan for DNFSB Recommendation 95-1* of October 16, 1995;
   b) *Systems Requirements Document,* K/TSO-001, Rev. 5, dated July 1998 (Section J, Attachment H);
   c) *Systems Engineering Management Plan, K/TSO-017,* Rev. 3, dated July 1998 (Section J, Attachment I);
   d) *Engineering Development Plan,* K/TSO-28, Rev. 3, dated July 1998 (Section J, Attachment J);
   e) *Project Management Plan, K/TSO-30,* Rev. 4, dated July 1999 (Section J, Attachment K);
   f) Applicable Safety Analysis Reports (References A, C, and D);
   g) The *State of Ohio EPA Directors Final Findings & Orders,* dated February 24, 1998 (Section J, Attachment E) — meet the requirements and sign the agreement as described in this document prior to commencement of S&M;
   h) The *State of Tennessee Department of Environment and Conservation Consent Order,* dated February 8, 1999 (Section J, Attachment D); and
   i) Any other applicable regulatory agreements or orders, including future agreements or orders.

   The Site Security Plan (D-10) and the Nuclear Materials Control and Accountability Plan (D-11) must be approved prior to transition of cylinder surveillance and maintenance.

2. Once cylinder S&M activities have been transitioned, the Contractor shall perform all activities necessary to manage the DOE UF_6 cylinder inventory, including required cylinder inspections, maintenance of the existing UF_6 cylinder

yards, design and construction of new cylinder storage yards, if required, and disposition of empty and heel cylinders. In addition, the Contractor shall be required to (1.) take receipt of newly generated USEC DUF_6 cylinders as described in the Memorandum of Agreement (MOA) between DOE and USEC dated June 30, 1998 (Reference F), and (2.) also to transfer in or out any other cylinders, estimated not to exceed 200 per annum. At the direction of DOE, the Contractor shall manage LEU or natural assay cylinders (e.g. transfer to other programs).

VII. Procurement of Long Lead Equipment

From the results of the CDR, the Contractor shall prepare and submit to DOE a **List of Major Equipment Items (D-20)** and a **Procurement Plan for Long-lead Items (D-21)**. The Contracting Officer or designee shall issue a notice-to-proceed for procurement of cylinder overpacks, if pursued, if such procurement is required prior to the issuance of the notice-to-proceed for cylinder management. The DOT certificate of cylinder overpack design, if pursued, shall be executed and costed under design activities. The cost of acquiring a fleet of DOE certified cylinder overpacks, if pursued, shall be included under cylinder management. Furthermore, the Contracting Officer or designee shall issue a notice-to-proceed for procurement of any long lead items associated with construction of the facilities if such items require acquisition prior to DOE issuance of the notice-to-proceed for construction. The cost of any long lead items associated with construction shall be included under construction activities.

VIII. Construction

1. The Contractor shall not begin Construction until the DOE Contracting Officer or designee issues a written notice-to-proceed. The Contractor has full responsibility for construction of the conversion facilities at Portsmouth, Ohio, and at Paducah, Kentucky. The Contractor shall obtain all permits for construction, including those required under federal, state, and local environmental compliance regulations and laws.

2. The Contractor shall be responsible for the following tasks:

   a) Site preparation at Paducah and Portsmouth for construction of the conversion facilities, including disposition and/or use of existing buildings, utilities, and infrastructure necessary to make way for the conversion facility, and construction of any needed buildings, roads, bridges, parking lots, and other infrastructure in support of conversion;
   b) Materials and labor for utilities and services extension from private or government installations (including telecommunications, firewater, sanitary water, electricity, natural gas, sewage, and railroads);
   c) Materials and labor for construction of the conversion facilities, including fire protection systems, process cooling and heating systems, and supplies;
   d) Preparation and execution of pre-operational test plans;
   e) System testing and operational readiness reviews;

f) Performing all necessary characterizations;
g) Disposal of construction debris and generated wastes during construction;
h) Permitting; and
i) Preparing and maintaining as-built drawings.

3. The Contractor shall generate a **Construction Management Plan (D-22).** At a minimum, this plan shall address the following areas:

   a) Temporary construction facilities and utilities;
   b) Labor availability, recruiting and training;
   c) Health, safety, fire protection and environmental aspects;
   d) Warehousing, receiving and protecting of equipment and materials;
   e) Expediting;
   f) Quality Assurance;
   g) Earned value systems;
   h) Constructibility reviews;
   i) Cost estimating, cost control, and reporting;
   j) Schedule and progress reporting;
   k) Security; and
   l) Pre-operational testing and operational readiness review

4. DOE will conduct an Operational Readiness Review (ORR) subsequent to the Contractor's completing its pre-operational testing and ORR and certifying the facility as operational. The Contractor shall not introduce process materials into the facility prior to receiving specific approval by the Contracting Officer or designee (after satisfactory completion of the DOE ORR).

5. Construction is complete at the successful completion of punch list items (i.e., ready for Beneficial Occupancy), pre-operational testing, operational readiness reviews (Contractor and DOE ORRs), receipt of as-built drawings, and acceptance by DOE of the conversion facilities.

IX. Conversion Operations

1. The Contractor shall not begin conversion operations until the Contracting Officer or designee issues a written notice-to-proceed following completion of the construction.

2. The Contractor shall safely process DUF_6 cylinders, irrespective of size, shape, condition, and/or contents identified in the Cylinder Information Database (CID), Reference E, and in the Memorandum of Agreement Between the Department of Energy and the United States Enrichment Corporation, relating to depleted uranium, dated June 30, 1998 (Reference F), at a rate such that the total DUF_6 inventory at all three sites could reasonably be converted and dispositioned in no longer than 25 years after conversion operations start, subject to constraints of projected funding levels.

3. The Contractor shall operate and maintain the facilities in accordance with DOE Order 5480.19, "Conduct of Operations Requirements for DOE Facilities," requirements of the clause entitled "Laws, Regulations, and DOE Directives" in Section I; and applicable permits and licenses to convert DUF_6 inventory to the selected chemically stable form at the maximum rate possible given the available funding provided by the Government.

4. The Contractor shall be responsible for any pre-conversion confirmation of cylinder contents and conditions necessary to establish that the DUF_6 feed to the conversion plant will meet the Contractor's acceptance criteria for DUF_6 feed. The Contractor also shall be responsible for any characterizations necessary to support applications for and approvals of all required operating permits; to ensure subsequent compliance with environmental regulations and the requirements of these permits; to verify the technical and economic performance of operations; to demonstrate compliance with occupational health and safety ordinances; and to quantify, classify, and certify products, wastes, and fugitive emissions from the conversion facility.

5. The Contractor shall be responsible for the safe, compliant storage of all cylinders and products/wastes until these cylinders, products, or wastes are transported off site and dispositioned (either acceptance and disposal by a licensed waste disposal site or transfer of title to another entity for use/reuse). The Contractor shall provide the capability to safely store for 6 months the empty cylinders and products/wastes generated from conversion. The method of storage of each of these materials, including hydrogen fluoride products stored either as HF or as a neutralized HF product, shall be considered in the NEPA safety analysis. The Contractor shall store radiological waste materials in accordance with DOE Order 435.1 as required by the clause entitled "Laws, Regulations, and DOE Directives" in Section I. Storage and packaging of all reactive fluorine products must conform, as appropriate, to federal, state, and local regulations for chemical hazards.

6. The Contractor shall be responsible for retrieving cylinders from the yards and transporting them to the conversion facilities. The Contractor shall process both good and degraded cylinders in a systematic manner and shall not purposely set aside degraded cylinders.

7. If the DOE or the Contractor identifies no market for either the DUF_6 conversion products or the empty cylinders, these materials shall be processed, packaged, and certified to meet the WAC at the federal disposal facility or at another licensed LLW repository. The processing of empty UF_6 cylinders would include washing, sectioning or crushing, loading into waste containers, and transporting for disposal. If the federal disposal facility is chosen, the Contractor shall transport the material to that site and transfer the material, certified for disposal, to the operating Contractor of federal disposal facility. If another licensed LLW repository is chosen, the Contractor shall be responsible for all disposition actions. Disposal of the conversion products and the all wastes shall be performed in accordance with all applicable local, state, and federal regulations. Wastes can include the empty cylinders, neutralization products [fluorides of calcium, sodium, and potassium (CaF_2, NaF, KF)], spent absorbents, solids generated from cylinder-washing operations, contaminated personal protective equipment, contaminated operating equipment

and tools, mixed waste, and other incidental wastes. If transuranic waste (as defined in DOE Order 435.1) are generated in the conversion operations and/or cylinder-washing operations, they shall be processed, characterized, packaged, and certified to meet the WAC of the Waste Isolation Project Plant (WIPP).

8. The Contractor shall define how it would deal with a suspension of plant operations caused by unforeseen events such as the inability of the LLW disposal site to receive products. The plan discussed shall allow safe, temporary shutdown without damage to equipment and without causing health, safety or environmental hazards.

9. The contractor shall annually survey and report to DOE the type (identification of radionuclides) and extent of contamination (pCi/cm^2) deposited on the internal and external surfaces of buildings, major process equipment items and interconnecting piping, and other points that may be determined to be prone to contamination accumulation (such as filter housings, effluent discharge points, material handling areas, etc.). The contaminants of concern are the isotopes of uranium ^{234}U, ^{235}U, ^{236}U, and ^{238}U and their daughters, and the contaminants associated with recycled uranium: ^{237}Np, ^{239}Pu, ^{241}Am, and ^{99}Tc.

10. The Contractor shall prepare a **Conversion Facilities Operations and Maintenance Plan (D-23)**. This plan shall incorporate the above responsibilities and be submitted to the Contracting Officer or designee for approval. The Contractor shall provide updates to this plan, as needed. This plan shall include startup, cylinder sequencing, staffing, staff training, shift operations including maintenance, development of procedures, policies for equipment maintenance, and parts replacement and spares.

11. As-Built drawings shall be maintained current throughout the term of this contract.

X. Related Services

In addition to the services specifically described in other provisions of this Statement of Work, the Contractor shall perform services as DOE and the Contractor shall agree in writing that will be performed from time to time under this contract at Paducah, Portsmouth, and/or Oak Ridge or elsewhere, as follows:

a) Services incidental or related to the services described in other provisions of this Statement of Work; and
b) Services, using existing or enhanced facilities and capabilities, for the NRC, under agency agreements between NRC and DOE.

XI. Deliverables

Listed below are the deliverables required in the Statement of Work. Other deliverables are also required in other provisions of the contract.

Deliverable number	Deliverable name	Schedule for deliverable (calendar days after contract award)	Allotted time for DOE review (calendar days after receipt)
D-1	Project Management Plan	60 days	60 days
D-2	Initial NEPA Data	120 days	–
D-3	Updated NEPA Data	with Preliminary Design Package	–
D-4	Regulatory and Permitting Management Plan	90 days	60 days
D-5	Project Quality Assurance Plan	90 days	60 days
D-6	Conversion Product Management Plan	120 days	30 days
D-7	Waste Management Plan	120 days	30 days
D-8	Integrated Safety Management System Plan	120 days	120 days
D-9	Radiation Protection Plan	90 days	60 days
D-10	Site Security Plan	120 calendar days prior to construction start	30 days
D-11	Nuclear Materials Control and Accountability Plan	120 calendar days prior to transition of Cylinder S&M	30 days
D-12	System Requirements Document	See Section F	60 days

Deliverable number	Deliverable name	Schedule for deliverable (calendar days after contract award)	Allotted time for DOE review (calendar days after receipt)
D-13	Conceptual Design Report Packages	See Section F	60 days
D-14	Preliminary Design Packages	See Section F	60 days
D-15	Conversion Facility Design (Final Design) Packages	See Section F	60 days
D-16	Preliminary Safety Analysis Reports	with Preliminary Design Package	90 days
D-17	Final Safety Analysis Reports	with Final Design Package	120 days
D-18	Plan to Transport ETTP Cylinders to Portsmouth	180 days	90 days
D-19	Cylinder Surveillance and Maintenance Plan	180 calendar days prior to transition of Cylinder S&M	30 days
D-20	List of Major Equipment items	with Preliminary Design Package	30 days
D-21	Procurement Plan for Long-Lead Items	per PMP	30 days
D-22	Construction Management Plan	with Final Design Package	60 days
D-23	Conversion Facilities Operations and Maintenance Plan	120 calendar days prior to commencing operations	60 days
D-24	Records Management Plan	90 days	30 days

XII. References

The following are incorporated into the contract by reference:

A. *SAR: Paducah Gaseous Diffusion Plant*, KY/EM-174, Volumes 1 & 2, December 1996; and Unresolved Safety Question Determinations (USQD) and Safety Evaluations for Paducah Gaseous Diffusion Plant for September 1995 - August 2000

B. Paducah, Portsmouth, and East Tennessee Technology Park (Map No. CJE 01-5.) - Site Maps

C. *SAR: Portsmouth Gaseous Diffusion Plant*, POEF-LMES-89, Volumes 1 & 2, January 1997; and Unresolved Safety Question Determinations (USQD) and Safety Evaluations for Portsmouth Gaseous Diffusion Plant for 1995 - August 2000

D. *K-25 Site UF_6 Cylinder Storage Yards Final Safety Analysis Report* dated February 1997; and Unresolved Safety Question Determinations (USQD) and Safety Evaluations for ETTP UF_6 Cylinder Storage Yards for October 1, 1996 - August 31, 2000 (Volumes 1 and 2).

E. Cylinder Information Database (CID). (The *CID System Documentation* is provided for information and proposal use only and includes "HTML Screen Shot Respective of the Existing CID System" and DRAFT "CID Computer System Design Document.")

F. MOA between USEC and DOE dated June 30, 1998.

G. American National Standards Institute (ANSI) N14.1 - 1995, for Nuclear Materials- Uranium Hexafluoride-Packaging for Transport

contractor is not expected to be required to have a facility clearance during the design and construction periods of the contract. During cylinder management and conversion operations, the Contractor may need to obtain security clearances (access authorizations) for employees who need unescorted access to cylinder yards which are located inside the security areas at Paducah, Portsmouth, and Oak Ridge. Therefore, the Contractor may be required to obtain a facility clearance before beginning cylinder management and conversion operations. The Contractor shall submit to DOE any necessary information to support obtaining a favorable FOCI determination, issuance of a facility clearance, and granting security clearances (access authorizations) for required employees. In the event that the Contractor is determined to be under FOCI, the Contractor shall develop an action plan acceptable to DOE to negate or reduce the unacceptable FOCI.

[End of Clause]

H. 38 TECHNICAL AND PERFORMANCE REQUIREMENTS

(a) It is expected that the Contractor will use the technical and performance parameters specified in its proposal as the basis for the development of all design documentation for the conversion of DUF_6, transport of cylinders and the disposition of waste and conversion products. Specifically, the contractor shall comply with the following fundamental technical and performance requirements in performance of the Statement of Work:

(1) Conversion Technology

DUF_6 will be converted to U_3O_8 and aqueous HF using the Framatome dry conversion process. The technology employed will consist of the following fundamental features:

- Autoclaves for DUF_6 vaporization.
- Dry conversion process using a fluidized bed reactor with DUF_6, steam, and hydrogen as feedstocks.
- Vacuum transfer of oxide product to the packaging station.
- Treatment of the process off-gas for recovery of aqueous HF meeting commercial specifications.

(2) Conversion Products

- U_3O_8 with a nominal packaged bulk density of 1.8 to 2.7 g/cc.
- Aqueous HF meeting commercial specifications as follows:

49%	70%
48.0 to 49.9% HF	70.0% HF minimum
U <= 1 ppm	U <= 1 ppm
Color – Clear	Color — Clear

(3) Plant Nominal Conversion Capacity

Paducah –18,000 MT DUF_6 per year
Portsmouth –13,500 MT DUF_6 per year

(4) Plant Waste Streams are as follows:

(i) Stack emissions: Emission streams consisting of process off-gas and containing trace uranium and fluorine

(ii) Contaminated Liquid waste streams: None

(iii) Low Level Radioactive Wastes:

- DUF_6 cylinders
- PPE and consumables
- HEPA filters

(iv) Hazardous Wastes:

- Fluids from maintenance activities (oils, hydraulic fluids)
- Laboratory acids and residues

(v) Mixed Wastes : none

(vi) Transuranic Wastes: none

(vii) Toxic Wastes: none

(viii) Other Wastes

- Sanitary waste water
- Cylinder yard waste (concrete and wooden chocks)
- CaF2 (if declared a waste)
- Miscellaneous garbage

(b) In the event this clause is inconsistent with the Statement of Work contained in Section C, this clause will have precedence.

[End of Clause]