

Spent Nuclear Fuel Management Cost Evaluation Report



March 1995

**U.S. Department of Energy
Office of Environmental Management
Office of Spent Fuel Management**



Department of Energy
Germantown, MD 20874-1290

March 23, 1995

Dear Reader:

The U. S. Department of Energy (DOE) has prepared this *Spent Nuclear Fuel Management Cost Evaluation Report*, (SNF-REP-PS-001) as part a commitment made in the *Assumptions and Methodology Document for the Spent Nuclear Fuel Management Cost Evaluation (AMD)* published in August 1994.

In June 1994, the Department issued the draft Spent Nuclear Fuel and Idaho National Engineering Laboratory Environmental Impact Statement (SNF and INEL EIS), which analyzed ten sites for the management of DOE-owned spent nuclear fuel, five DOE sites and five Navy sites (for naval spent nuclear fuel only.) The period of time covered by the EIS is 40 years. This amount of time may be required to make and implement a decision on the ultimate disposition of all type of SNF. In addition, the Department has been directed by Congress to prepare a Baseline Environmental Management Report (BEMR) which provides life-cycle costs for the Environmental Management Program. This cost report provides relative comparisons among the SNF and INEL EIS alternatives. The report goes beyond the scope of the EIS, by analyzing relative program costs for life-cycle management of DOE SNF, including ultimate disposition, for program and BEMR purposes. Cost information from this report will be used in several ways:

- As a basis for further cost studies and budget formulation,
- provide relative cost data to be used in the consideration of decisions resulting from the analysis contained in the SNF and INEL EIS, and
- to support the DOE's BEMR to Congress.

FOR FURTHER INFORMATION CONTACT: Mr. Brian Edgerton, U.S. Department of Energy, Idaho Operations Office, 850 Energy Plaza, MS 1136, Idaho Falls, Idaho, 83401, at (208) 526-1081.

Sincerely,

A handwritten signature in black ink, appearing to read "John J. Jicha, Jr." with a stylized flourish at the end.

John J. Jicha, Jr., Director
Office of Spent Fuel Management
Office of Waste Management
Environmental Management

Spent Nuclear Fuel Management Cost Evaluation Report



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EXECUTIVE SUMMARY

This report summarizes the Department of Energy (DOE) evaluation of potential costs associated with management of DOE spent nuclear fuel (SNF) for an interim period (up to 40 years) until ultimate disposition. In June 1994, the Department released the draft *SNF and INEL EIS*¹, which outlines five alternatives² for where to manage DOE's inventory of SNF for the interim period. The cost estimate provides relative cost comparisons among the *SNF and INEL EIS* alternatives, which consider interim storage only. But the evaluation goes beyond the scope of the EIS to analyze program costs for life-cycle management of DOE SNF. It will allow DOE to include consideration of estimated life-cycle costs in the decision-making process, and may form a base for initial planning towards ultimate disposition. This baseline cost information is also being used to support the Department's Environmental Restoration and Waste Management (including SNF management) Baseline Environmental Management Report, which will be issued in the spring of 1995.

Costs of potential decisions are typically not evaluated in an EIS, but the Department recognizes that the financial implications of its future programs are important considerations for decision-making and has resolved to inform the public about those costs. As part of that commitment, DOE released the *Assumptions and Methodology Document for the Spent Nuclear Fuel Management Cost Evaluation (AMD)* in August 1994. This cost report fulfills DOE's specific commitment, made in the AMD, to make cost information available to the public before the *SNF and INEL EIS* Record of Decision is issued by June 1995. The results of the cost evaluation and public input received on the AMD are among the factors that DOE will consider when preparing the Record of Decision.

APPROACH

For the cost evaluation, two SNF life-cycle management strategies were developed and considered in parallel with an interim storage strategy. The costs associated with each were calculated. The approach taken and a few definitions of terms are presented below.

Strategies — For the purpose of this evaluation, a management strategy is defined as the manner in which DOE's SNF is managed (for example, Storage Only, storage with Direct Disposal, and storage with Processing). It is important to distinguish "strategies" (developed for this report) from "alternatives" (management options presented in the EIS). Throughout this report "alternative" will refer to *where* the SNF is managed, whereas, "strategy" will refer to *how* the SNF is managed.

¹*DOE Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Draft Environmental Impact Statement*

²See Table S-1 at the end of this Executive Summary for a listing of the alternatives. The reader is directed to Volume 1 of the EIS for an in-depth presentation of the alternatives.

Three strategies were developed for this report and were analyzed for managing SNF that DOE is currently responsible for.

Storage Only - interim storage of SNF for 40 years, the basis of the EIS alternatives, is an interim SNF management strategy only (*not* SNF life cycle),

- **Direct Disposal** - storage followed by direct disposal [without modification of the fuel matrix except for potential Resource Conservation Recovery Act (RCRA) treatment] in a geologic repository, and
- **Processing** - storage followed by processing (chemical separation of fissile material and immobilization of resultant high level waste) and high-level waste disposal in a geologic repository.

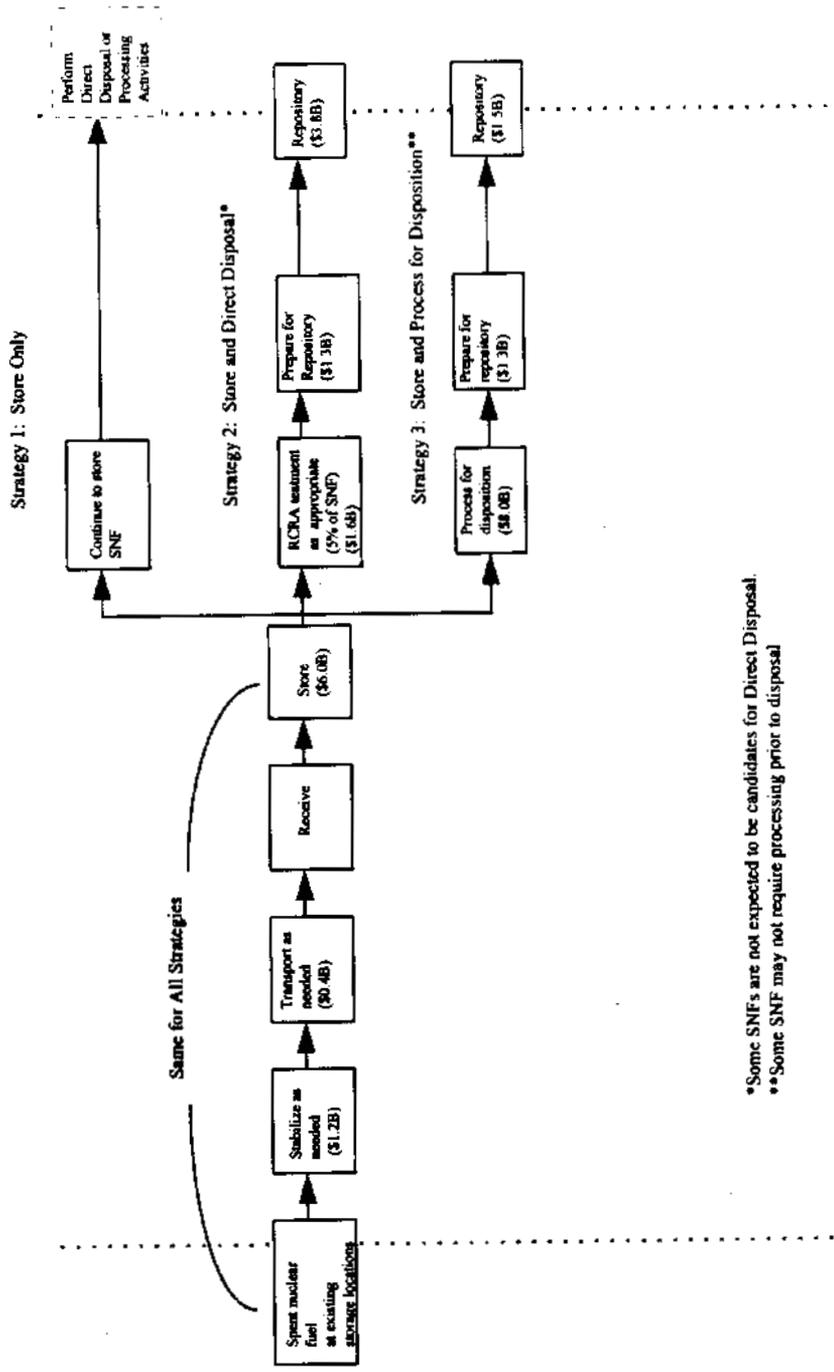
Figure S-1 is an overview of the strategies and functions analyzed in this report. As the figure shows, Direct Disposal and Processing address ultimate disposition of the SNF or resultant high level waste in a repository. Costs in the figure represent estimates for a hypothetical "green field" situation in which management of DOE SNF is performed at a site with no existing SNF facilities. These costs do not include the costs associated with functions at other sites, such as, D&D, preparation for shipping, or transitional SNF management. Because of the unknown variables (such as repository waste acceptance criteria or processing technology) and their large uncertainty, *the cost of the life-cycle strategies cannot be compared directly on the basis of this report.*

Cost Ranges — Because of the very broad scope associated with complex-wide SNF management and the uncertain nature of future actions, it is not possible to develop "best estimate" costs at this time. Alternatives within the *SNF and INEL EIS* describe different facilities, each managing varying amounts of SNF. The degree to which existing facilities factor into a given alternative can vary. To account for this, each alternative was analyzed for two cost ranges to define the possible spread of cost for each alternative. The Lower Cost Range considers maximum use of existing facilities; the Upper Cost Range minimizes such use.

Scenarios — To analyze costs involved with future actions for managing DOE SNF, scenarios were developed to describe various possible management schemes. A scenario describes SNF management for one alternative, under one of the three strategies, and for one cost range. The major alternatives (11 total) for the Decentralization, 1992-1993 Planning Basis, Regionalization, and Centralization alternatives resulted in a total of 66 scenarios; the No Action alternative added two more (No Action analyzed for Storage Only strategy exclusively).

Analysis — A commercially available spreadsheet program was used to combine, calculate, and analyze data for all scenarios. Gathering data, building the spreadsheet, and using the information encompassed many steps, including:

- identifying current and future SNF inventories by type, location, and amount,
- determining transportation costs,



*Some SNF are not expected to be candidates for Direct Disposal.
 **Some SNF may not require processing prior to disposal

Figure S-1. Overview of postulated strategies for managing SNF with costs for a "green field" centralization situation.

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- identifying the dollar value and potential uses of current facilities,
- identifying generic functions,
- developing costs and schedules for the generic facilities,
- defining site-specific requirements for each scenario,
- developing a scaling exponent to adjust facility costs for capacity, and
- performing the calculations.

Peer Review — The input data and spreadsheet were subject to peer review by personnel from the primary DOE sites being considered and were revised accordingly. An evaluation (sensitivity analysis) was performed to determine the sensitivity of the results to changes in variables.

COST BASIS

All planning is based upon application of current knowns and conjecture. It would be impossible to factor in all the possible permutations in fuel type and management strategy, potential new technologies, future regulations, economics, etc.. Many assumptions were used in the cost evaluation to provide a common basis that allows for comparison among the alternatives. Significant assumptions are as follows:

- Costs are expressed as Upper and Lower Cost Ranges,
 - Upper Range* - Assumes construction of new facilities, except for those judged adequate for 40 years [RCRA treatment is included under Direct Disposal for 5% (by MTHM) of total SNF inventory],
 - Lower Range* - Assumes use of some existing facilities at Hanford, INEL, and SRS,
- Facility upgrades are limited to Phase III vulnerability costs (\$586M),
- D&D costs for new facilities are included. D&D costs for existing facilities were assumed to be sunk costs and were not included, and
- Full repository cost recovery is included (\$3.7B).

While all combinations of East/West Regionalization (4B) were considered, only the INEL/SRS option was calculated as it has a minimum \$1B advantage over other combinations. INEL was found to be the least costly western site because of its existing storage capability, which could likely be used through 2035, and because it is the current site of the Expanded Core Facility (ECF). SRS is the least costly eastern site because most eastern SNF is currently managed at the SRS, which has existing SNF management capacity that may be utilized. The estimated cost to manage this SNF at the Oak Ridge Reservation exceeds the cost to keep it at the SRS.

RESULTS

The costs for each alternative are presented for the Storage Only, Direct Disposal, and Processing strategies. To simplify presentation of results, each alternative is compared to the Planning Basis alternative, which reflects DOE's management of SNF in the recent past. Separate graphs for the Upper Cost Range and the Lower Cost Range are included for each strategy. Costs are presented and discussed as total constant year dollars (1995). Net present values were also calculated for each alternative, but the NPV comparison was not found to differ from the constant dollar alternative comparison.

Storage Only

Under the Storage Only strategy, SNF is held in interim storage for 40 years and no measures are taken to prepare the spent fuel for ultimate disposition. NOTE: Because this is an interim measure that does not address ultimate disposition of DOE SNF, the *costs for Storage Only cannot be compared to the life-cycle strategies (Direct Disposal and Processing)*.

Upper Cost Range — Figure S-2 shows that alternatives 1, 2A, 2B, or 4A are roughly equivalent to the Planning Basis because most SNF is located at the same sites (Hanford, INEL, and SRS) in each alternative. Regionalization 4B costs 11% less than the Planning Basis because all SNF is moved to two sites (INEL and SRS), which have existing SNF infrastructures, and economies of scale (it is more cost effective to build and operate one large facility than to build and operate several smaller facilities with the same combined capacity) dictate that two sites are less costly than three. Figure S-2 also shows that if new facilities are built due to vulnerabilities or other considerations, it is least expensive to build all of the facilities at one site that currently has an existing SNF infrastructure (i.e., alternatives 5A, 5B, or 5C). In that case, the cost savings range from 14% to 23 % over the Planning Basis alternative. Centralization at sites with no SNF infrastructure, alternatives 5D and 5E, are roughly equivalent to the Planning Basis alternative.

Lower Cost Range — If existing facilities can continue to be used for the Storage Only strategy, then it is least expensive to manage fuel under alternatives that maximize use of sites with existing capabilities (i.e., alternatives 2A, 2B, 3, 4A, 4B, or 5C). The centralization alternatives, which would require new construction of storage facilities, cost 1% to 64% more than the Planning Basis. Centralization alternative 5C is roughly equivalent to the Planning Basis alternative because of the use of existing facilities at the Savannah River site with minimal upgrades.

Discussion — The expected costs would likely be somewhere in the middle where some existing facilities could continue to be utilized, at least for a limited time. In that case, the cost difference between alternatives that manage fuel at fewer sites (3, 4A, and 4B) could be small, given the degree of uncertainty for future actual costs (see Section 7).

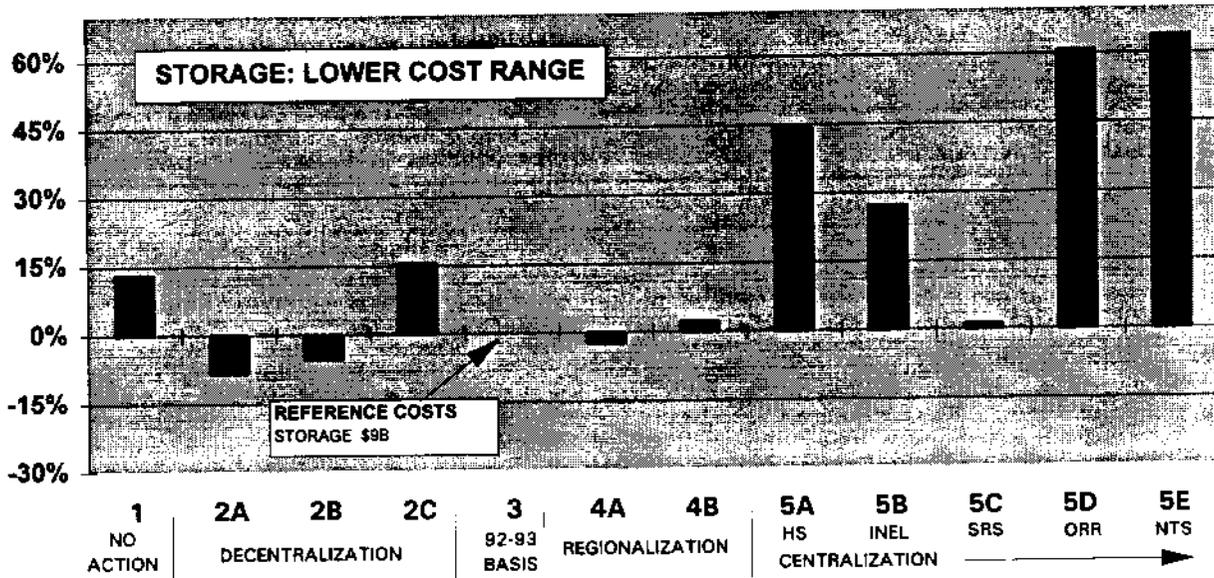
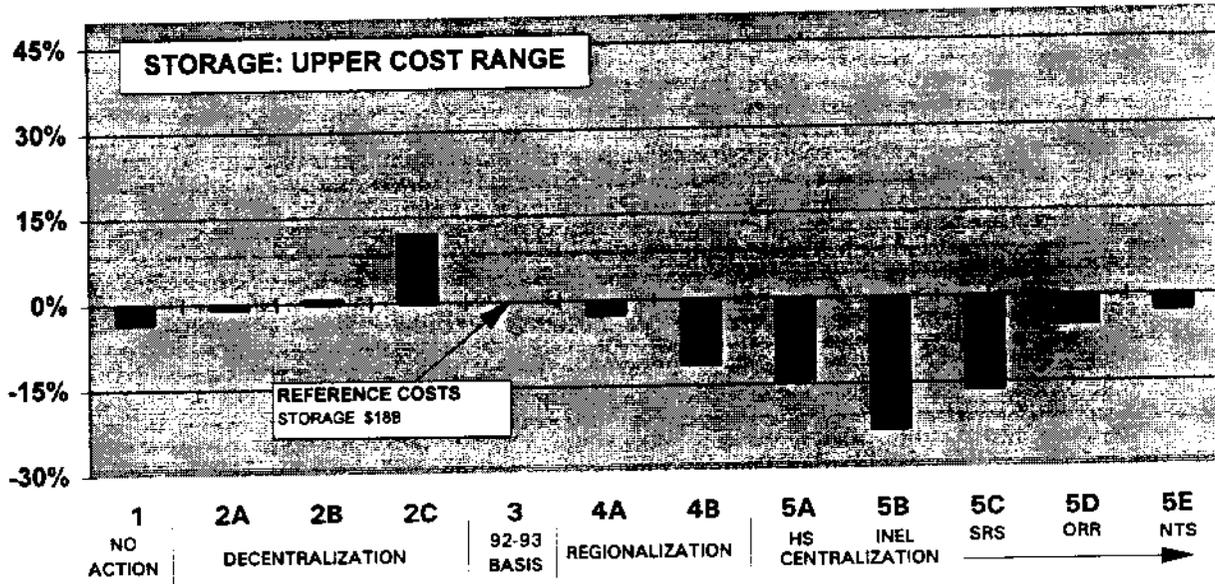


Figure S-2. Storage Only: Comparison of alternatives to the 1992/93 Planning Basis for the Upper and Lower Cost Ranges.

Direct Disposal

The Direct Disposal strategy assumes storage followed by direct disposal (without modification of the fuel matrix except for potential RCRA treatment) in a geologic repository.

Upper Cost Range — Figure S-3 shows that Decentralization 2A, 2B, and 2C are roughly 16% to 25% more expensive than the Planning Basis. This result is directly related to performing costly functions in a decentralized manner requiring large capital investments at multiple sites, i.e., canning and characterization, and RCRA treatment. Regionalization 4A is slightly less costly than the Planning Basis. Regionalization 4B (INEL and SRS) is less expensive than the Planning Basis alternative because of economies of scale. Centralization is 10% to 21% less expensive than the Planning Basis alternative due to economies of scale (i.e., building and operating facilities in a consolidated manner).

Lower Cost Range — Figure S-3 shows that Decentralization 2A, 2B, and 2C are roughly 20% to 33% more expensive than the Planning Basis. The reasons are the same as stated for the Upper Cost Range. As the figure illustrates, Alternative 4A costs 5% less than the Planning Basis. This is because new facilities to package the SNF must be built under all alternatives, and the mix of facilities to manage SNF by fuel type under 4A optimizes use of existing facilities at INEL and SRS. Alternatives 4B, 5A, 5B, and 5C are 3% to 12% more than the Planning Basis because the cost incurred by duplication of facilities during the transition period override the cost savings that would be realized due to economies of scale. Alternatives 5D and E are roughly 20% more expensive than the Planning Basis because of the lack of existing SNF infrastructure at the Oak Ridge and Nevada sites.

Discussion — Overall, the Decentralization alternatives are more expensive for this strategy than any other alternatives because of the duplication of processing facilities that would be required. Centralization at Oak Ridge or the Nevada Test Site would also require a large amount of new construction. A scenario in which some existing facilities could continue to be utilized largely eliminates the cost difference between alternatives 3, 4A, 4B, 5A, 5B, and 5C, given the degree of uncertainty for future actual costs (see Section 7).

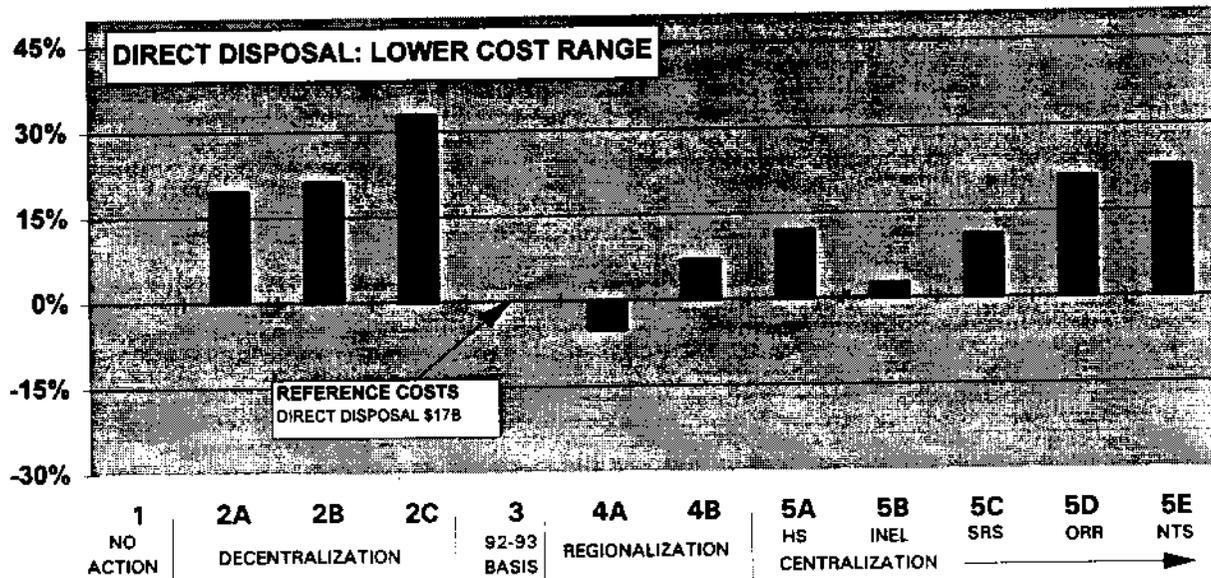
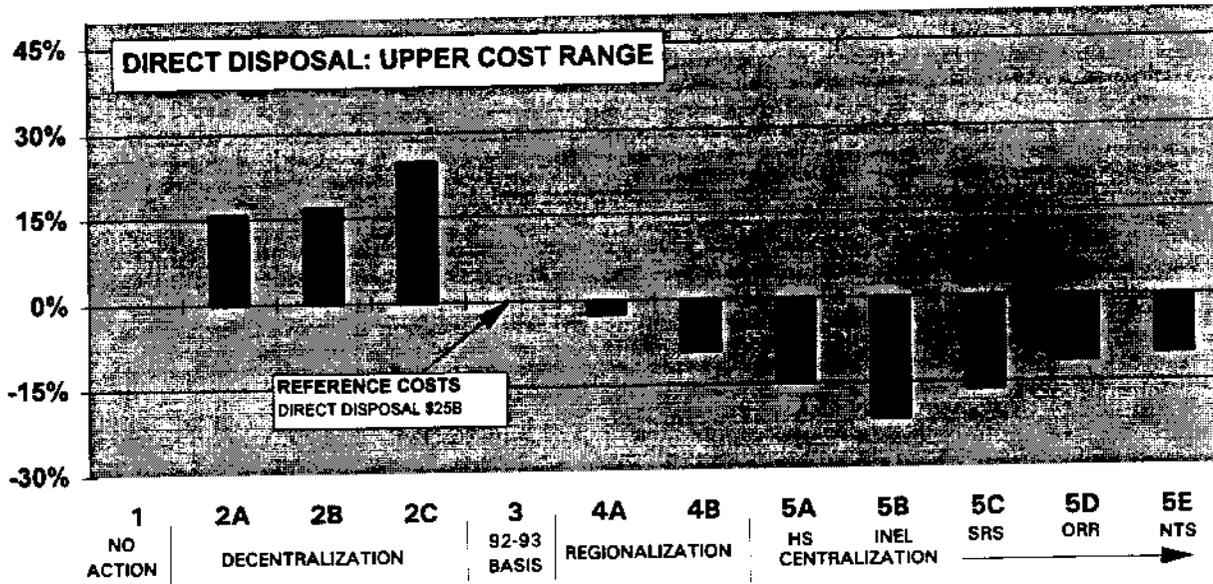


Figure S-3. Direct Disposal: Comparison of alternatives to the 1992/93 Planning Basis for the Upper and Lower Cost Ranges.

Processing

The Processing strategy is defined as storage followed by processing (chemical separation of fissile material and immobilization of resultant high level waste) and high-level waste disposal in a geologic repository.

Upper Cost Range — Figure S-4 shows that Decentralization 2A, 2B, and 2C are 21% to 30% more expensive than the Planning Basis. This result is directly related to performing costly processing functions requiring large capital investments at multiple sites. Regionalization by Fuel Type (4A) and Regionalization by Geography (4B-INEL and SRS) are less expensive than the Planning Basis because of economies of scale. Centralization 5A, 5B, and 5C are 6% to 15% less expensive than the Planning Basis alternative due to economies of scale (i.e., building and operating facilities in a consolidated manner). Centralization 5D and 5E are roughly 15% more expensive due to lack of existing SNF infrastructure at the Oak Ridge and Nevada sites.

Lower Cost Range — Once again, the graph shows that managing SNF at sites with existing facilities is generally less expensive. Centralization 5C costs 28% less than the Planning Basis because of the number of existing processing facilities that were assumed to be used with minimal upgrades.

Discussion — Overall, the Decentralization alternatives are vastly more expensive for this life-cycle strategy than any other alternatives because of the duplication of processing facilities that would be required. Centralization at Oak Ridge or the Nevada Test Site would also require a large amount of new construction. A scenario in which some existing facilities could continue to be utilized largely eliminates the cost difference between alternatives 3, 4A, 4B, 5A, 5B, and 5C, given the degree of uncertainty for future actual costs (see Section 7).

SENSITIVITY

A number of conditions, variables, and unknowns (which are discussed in the body of this report) could have significant impact on the cost of managing DOE's spent fuel, among them:

- Scaling factors,
- A delayed repository opening could add up to 1% of total life-cycle costs per year to life-cycle strategies,
- Restricted high enriched uranium disposal limits could significantly increase the cost for the Direct Disposal strategy,
- Applicability of RCRA regulations, and
- The extent to which existing facilities can continue to be used and changes in regulations, DOE Orders, etc..

While the first four cost risks outlined here may affect the total cost of implementation, only the last bulleted item will affect the comparison of alternatives.

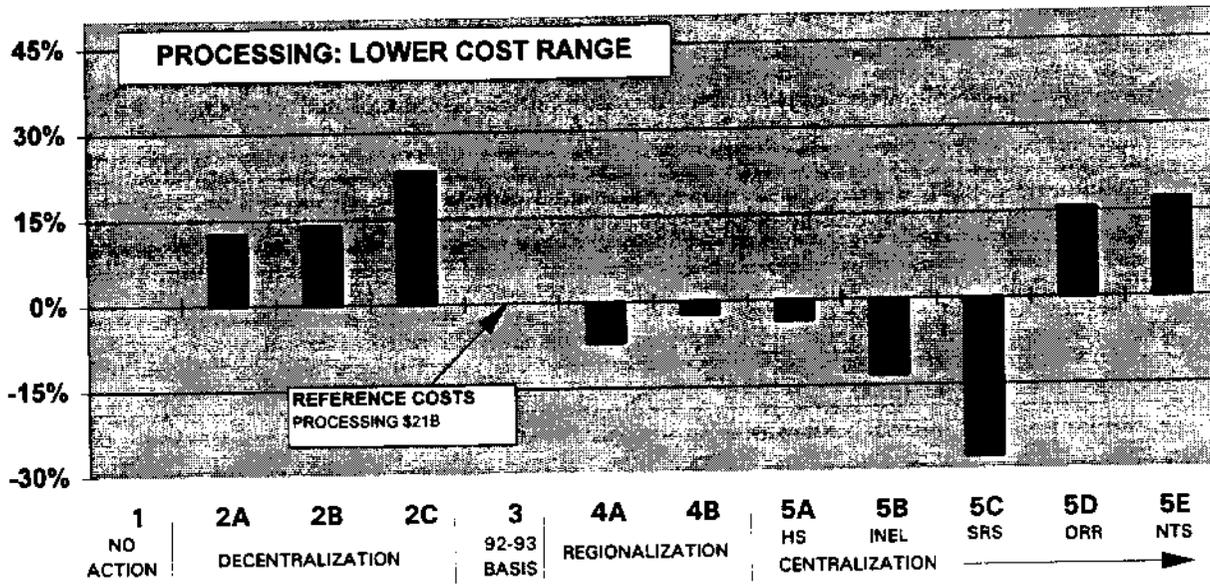
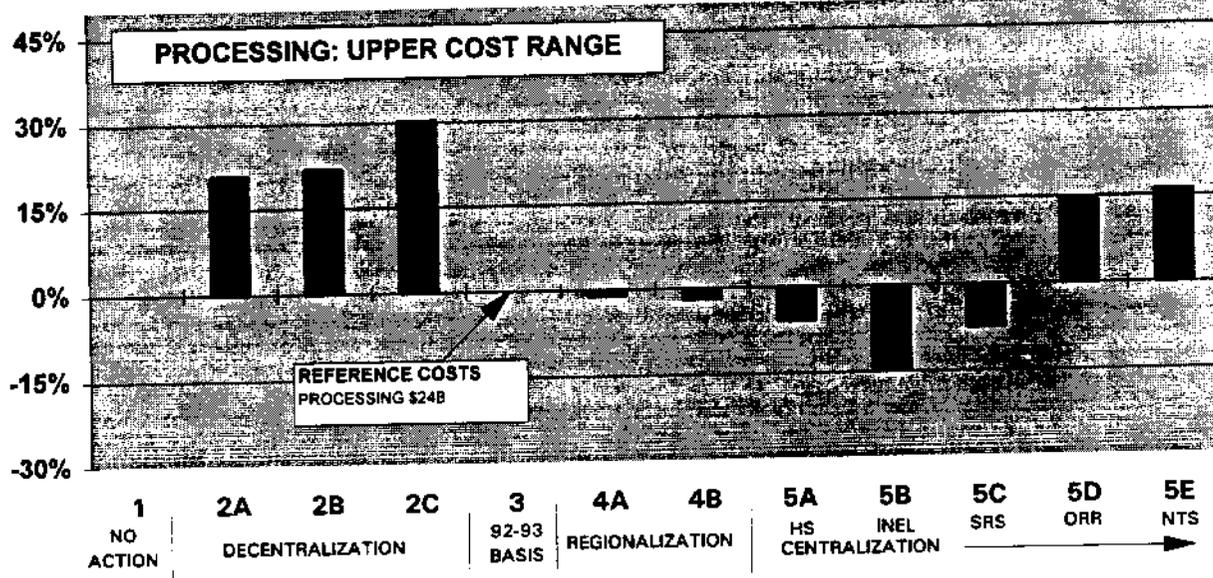


Figure S-4. Processing: Comparison of alternatives to the 1992/93 Planning Basis for the Upper and Lower Cost Ranges.

CONCLUSIONS

The extent to which existing facilities are used is a primary variable that affect the costs of life-cycle management. If new facilities are required, it is least expensive to centralize and build at one site that has existing SNF infrastructure (i.e., 5A, 5B, 5C). The cost savings for all strategies result from economies of scale. It is more cost effective to build and operate one large facility than to build and operate several smaller facilities with the same combined capacity. These economies of scale for utilizing larger, co-located facilities more than offset increased transportation costs. Transportation costs, which are typically 1% of total costs, are not an overriding cost consideration in selection of locations for SNF management.

A scenario in which a significant number of existing facilities could be upgraded at low cost, largely eliminates the cost difference between alternatives 3, 4A, 4B, 5A, 5B, and 5C, given the uncertainty in actual cost. The economies of scale are offset by reduced capital costs. Before drawing conclusions based on the Lower Cost Range results, the reader should recognize that selection of an approach using existing facilities with expensive upgrades, (over and above correction of known vulnerabilities¹) significantly changes the cost comparisons. In this situation, cost would tend to increase toward the Upper Cost Range.

Based on this cost evaluation, it is not possible to determine whether Direct Disposal or Processing is the least expensive ultimate disposition strategy. It is likely that this determination is fuel-specific. The uncertainty regarding repository waste acceptance criteria, processing technology selection, applicability of RCRA, etc., overwhelm any apparent differences.

An early repository opening resulting in shutdown of some SNF management sites could significantly lower total Department costs on a constant year dollar basis.

¹DOE recently assessed its SNF storage facilities for vulnerabilities (conditions that pose current or future safety problems requiring action). The Action Plan (Reference 3) proposes near-term corrections of these vulnerabilities. Long-term actions may also be required at a later point in time.

Table S-1. Locations of Spent Nuclear Fuel Management by Alternative

Spent Nuclear Fuel Alternative	Management Locations
1. No Action	Current locations (about 100 including university and foreign sites ¹)
2. Decentralization 2A No naval fuel exam 2B Limited naval fuel exam 2C Full naval fuel exam	Hanford, INEL, NNPP, ORR, SRS, and 5 other DOE sites
3 1992/1993 Planning Basis	Hanford, INEL, SRS
4A Regionalization by Fuel Type	Hanford, INEL, SRS
4B Regionalization by Geography	INEL and SRS (other options are not addressed herein)
5A Centralization at Hanford	Hanford
5B Centralization at INEL	INEL
5C Centralization at SRS	SRS
5D Centralization at ORR	ORR
5E Centralization at NTS	NTS
Hanford INEL NNPP NTS ORR SRS	Hanford Site Idaho National Engineering Laboratory (as used here, INEL includes Argonne National Laboratory - West and the Naval Reactor Facility) Naval Nuclear Propulsion Program (Kesselring Site and Norfolk, Pearl Harbor, Portsmouth, and Puget Sound Naval Shipyards) Nevada Test Site Oak Ridge Reservation Savannah River Site
1. Foreign sites are described in the <i>SNF & INEL EIS</i>	

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GLOSSARY

Alternative(s)	The locations and quantities of SNF, as defined by the SNF & INEL EIS
AMD	Assumptions and Methodology Document
ANL-E	Argonne National Laboratory - East
B&W	Babcock and Wilcox
BNL	Brookhaven National Laboratory
Canning	Process of packaging spent nuclear fuel and wastes in canisters to assure containment of fission products for storage or disposal
Cash Flow	Amount of money required on an annual basis
Characterization	The process of determining the physical and radiological properties (characteristics) of spent nuclear fuel and waste
Committed cost	Unavoidable expenses currently planned or required that will not be incurred specifically as a result of future decisions
Constant-year dollars	Dollars in terms of current (1995) buying power
D&D	Decontamination and decommissioning
DEIS	Draft environmental impact statement
Discount rate	The interest rate used in calculating the present value of expected yearly benefits and costs.
DOE	Department of Energy
ECF	Expended Core Facility
Economics of scale	Cost benefits realized by concentrating activities in fewer, larger facilities
EIS	Environmental impact statement
FRR	Foreign Research Reactor
FSVR	Fort St. Vrain Reactor Site
Function	Facility-related function or activity related to SNF management.
Hanford	Hanford Site
INEL	Idaho National Engineering Laboratory
LANL	Los Alamos National Laboratory
Life cycle	Refers to managing spent nuclear fuel from its current configuration through ultimate disposition of the fuel and associated waste
Life-Cycle Cost	Cost associated with SNF management until disposition
LITCO	Lockheed Idaho Technologies Co.
Management Strategy	A postulated manner in which the SNF is managed
MPC	Multipurpose container
MTHM	Metric tons of heavy metal
MTU	Metric ton uranium
MRS	Monitored retrievable storage

NNPP	Naval Nuclear Propulsion Program
NPV	Net present value-- allows the life-cycle costs to be compared with consideration of inflation and interest.
NRF	Naval Reactors Facility
NTS	Nevada Test Site
O&M	Operation and maintenance
OCRWM	DOE Office of Civilian Radioactive Waste Management
OMB	Office of Management and Budget
ORR	Oak Ridge Reservation
Processing	For this evaluation, processing included chemical separation of fissile material from other constituents of SNF, and immobilization of resultant high level waste
RCRA	Resource Conservation Recovery Act
Relative Costs	A set of costs developed using a common basis for comparison
Reprocessing	Processing with the intent to recover special nuclear materials
Scaling exponent	A number (derived using known facility cost as a basis) used to adjust capital and O&M costs for facilities of different capacities
Scenario	A postulated set of actions defined by a combination of decisions among SNF alternatives and management strategies.
Sensitivity	The extent to which results change in response to a change in variables or assumptions
SNF	Spent nuclear fuel
SNF & INEL EIS	Draft DOE Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Draft Environmental Impact Statement
SNL	Sandia National Laboratory
SRS	Savannah River Site
Strategy	The postulated manner in which DOE's SNF is managed (Storage Only, Direct Disposal, Processing).
Sunk cost	A committed cost
Vulnerabilities	Recognized current or future safety problems requiring action
WAC	Waste acceptance criteria
WVDP	West Valley Demonstration Project

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1. INTRODUCTION AND BACKGROUND

The U.S. Department of Energy (DOE) has issued a draft environmental impact statement for its spent nuclear fuel (SNF) management program, the *DOE Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Draft Environmental Impact Statement (SNF & INEL EIS)* (Reference 1). The text box to the right summarizes the alternatives considered in the *SNF & INEL EIS*. DOE has performed a cost evaluation of these alternatives to aid in making programmatic SNF decisions. This report presents the results of that effort.

This cost estimate provides relative cost comparisons among the *SNF and INEL EIS* alternatives, which consider interim storage only. But the evaluation goes beyond the scope of the EIS to analyze program costs for life-cycle management of DOE SNF. It will allow DOE to include consideration of estimated life-cycle costs in the decision-making process, and may form a base for initial planning towards ultimate disposition. This baseline cost information is also being used to support the Department's Environmental Restoration and Waste Management (including SNF management) Baseline Environmental Management Report, which will be issued in the spring of 1995.

DOE considers cost an important factor for implementing Department activities and, therefore, wanted to receive public input on this cost evaluation process. DOE issued the *Assumptions and Methodology Document for the Spent Nuclear Fuel Management Cost Evaluation* (AMD, Reference 2) for public comment on August 17, 1994. The AMD was made available at over 30 EIS public meetings before the comment period closed on September 30, 1994.

The public submitted 36 comments specific to the information contained in the AMD, addressing the following general themes:

- Commentors felt that while U.S. policy appears to exclude reprocessing of SNF, the AMD discusses processing as a potential management strategy. Several comments expressed a desire to restart reprocessing activities.

SNF & INEL EIS Alternatives for Managing DOE SNF

No Action - Take minimum actions required for safe and secure management of SNF at or close to the generation site or current storage location.

Decentralization - Store most SNF at or close to the generation site or current storage location, with limited shipments to DOE facilities.

1992/1993 Planning Basis - Transport and store newly generated SNF at the Idaho National Engineering Laboratory or Savannah River Site.

Regionalization - Distribute existing and projected SNF among DOE sites based primarily on fuel type (Subalternative A) or geographic location (Subalternative B).

Centralization - Manage existing and projected SNF inventories from DOE and the Navy at one site until ultimate disposition.

- Commentors asked why the AMD and the cost estimates to be generated in the cost report were not included as an integral part of the EIS.
- Commentors indicated a desire to comment on the final cost report.
- Commentors were concerned about the extended use of the existing facilities identified in the AMD and the potential unforeseen costs associated with their use.
- Historic operation and maintenance (O&M) costs may not be indicative of the future O&M costs to comply with expanding regulatory requirements.
- The AMD lacks detail.

Each of the public comments on the AMD was reviewed to identify proposed revisions to the assumptions and methodology. It was determined that the public comments received are addressed in the assumptions and methodology outlined in this report. Several comments focused on lack of detail in the AMD. Neither the AMD nor the cost report are intended to provide the details necessary for DOE budgetary planning needs. The cost report does, however, contain sufficient detail to support the Department's programmatic decisions on where to manage DOE-owned SNF.

2. PURPOSE

This cost report provides DOE and the public with information on both the interim and the long-term financial implications of DOE decisions on SNF management locations. This cost evaluation is a tool to help DOE make decisions that incorporate cost-effective management of SNF.

Decisions made today could impact future costs, especially if eventual decisions on management strategies result in relocation of SNF or duplication of facilities. Some key decisions for SNF management probably will not be made for several years. For example, future decisions on how to prepare SNF for ultimate disposition or selection of technologies for managing SNF could significantly affect overall program cost. Therefore, DOE is examining postulated management strategies that include ultimate disposition of its SNF. Because of the uncertainties in exact technologies, it was deemed prudent to utilize relative cost estimates for evaluating SNF scenarios.

The cost report has the following purposes:

- To help DOE make relative program cost comparisons among the *SNF & INEL EIS* alternatives.
- To provide helpful information to DOE in its effort to establish life-cycle program costs,
- To fulfill DOE's commitment to make cost information available to the public before the *SNF and INEL EIS* Record of Decision is issued in June 1995, and
- To provide information for use in supporting the Department's Environmental Restoration and Waste Management (including SNF management) Baseline Environmental Management Report, which will be issued in the spring of 1995.

The *SNF & INEL EIS* is intended to support decisions regarding the location of SNF management facilities until a decision on its ultimate disposition is made. To fulfill the first purpose, the cost evaluation determines the relative program costs associated with a

Definitions

Alternatives - The locations and quantities of SNF as defined by the *SNF & INEL EIS* alternatives, subalternatives, and options.

Constant Year Dollars - Cost measured in terms of the buying power of a 1995 dollar that is not affected by general inflation.

Discount Rate - The interest rate used in calculating the present value of expected yearly benefits and costs.

Net Present Value - The present value of an investment based on a series of periodic cash flows and a discount rate. The net present value of an investment is today's value of a series of future payments (negative values) and income (positive values).

Life-Cycle Cost - Cost associated with management of SNF from its current configuration through ultimate disposition of the fuel and associated waste.

Management Strategy - The postulated manner in which DOE's SNF is managed (for example, Storage Only, storage with Direct Disposal, and storage with Processing).

Scenario - A postulated set of actions defined by a combination of decisions among SNF alternatives and management strategies.

Economies of Scale - Cost benefits realized by concentrating activities in fewer, larger facilities.

Cost Range - The cost ranges define the possible spread of costs for each alternative. The Lower Cost Range considers maximum use of existing facilities; the Upper Cost Range minimizes such use.

strategy for storing SNF for 40 years for each location and associated spent fuel inventory (alternative) identified in the *SNF & INEL EIS*.

3. SCOPE OF THE COST EVALUATION

This cost report evaluates a range of relative costs for alternatives identified in the *SNF & INEL EIS* (see Section 3.1 below). Throughout this report “alternative” will refer to *where* the SNF is managed whereas, “strategy” will refer to *how* the SNF is managed.

3.1 Alternatives

This cost evaluation addresses 12 alternatives analyzed by the *SNF & INEL EIS*, as shown in Figure 3-1. Table 3-1 lists the locations at which SNF may be managed during the 40-year period. All locations currently managing SNF will continue to do so for at least a limited time under all alternatives, but only locations designated in Table 3-1 were assumed to manage SNF for the 40-year period. While the decision on managing DOE SNF that will be presented in the Record of Decision could be a hybrid (i.e., incorporate portions of two or more alternatives), possible hybrid alternatives were not developed or analyzed for this report.

3.2 Management Strategies

A cost comparison of alternatives depends on the SNF actions to be taken (that is, the postulated management strategies). Based on these alternatives, DOE has proposed the following SNF management strategies for use in this report:

Storage Only - interim storage of SNF for 40 years (not SNF life cycle),

Direct Disposal - storage followed by direct disposal [without modification of the fuel matrix except for potential Resource Conservation Recovery Act (RCRA) treatment] in a geologic repository, and

Processing - storage followed by processing (chemical separation of fissile material and immobilization of resultant high level waste) and high-level waste disposal in a geologic repository.

Direct Disposal and Processing address ultimate disposition of the SNF or associated high level waste in a repository. Figure 3-2 depicts the major steps in each strategy (more details are provided in Appendix A). Costs in the figure represent estimates for a hypothetical “green field” situation in which management of DOE SNF is performed at a site with no existing SNF management facilities. These costs do not include the costs associated with functions at other sites, such as, D&D, preparation for shipping, or transitional SNF management.

Figure 3-1 depicts the scenarios (the specific alternatives, management strategies, and cost ranges) evaluated. There are many potential variations on the implementation of a given management strategy. For example, different technologies could be utilized and different

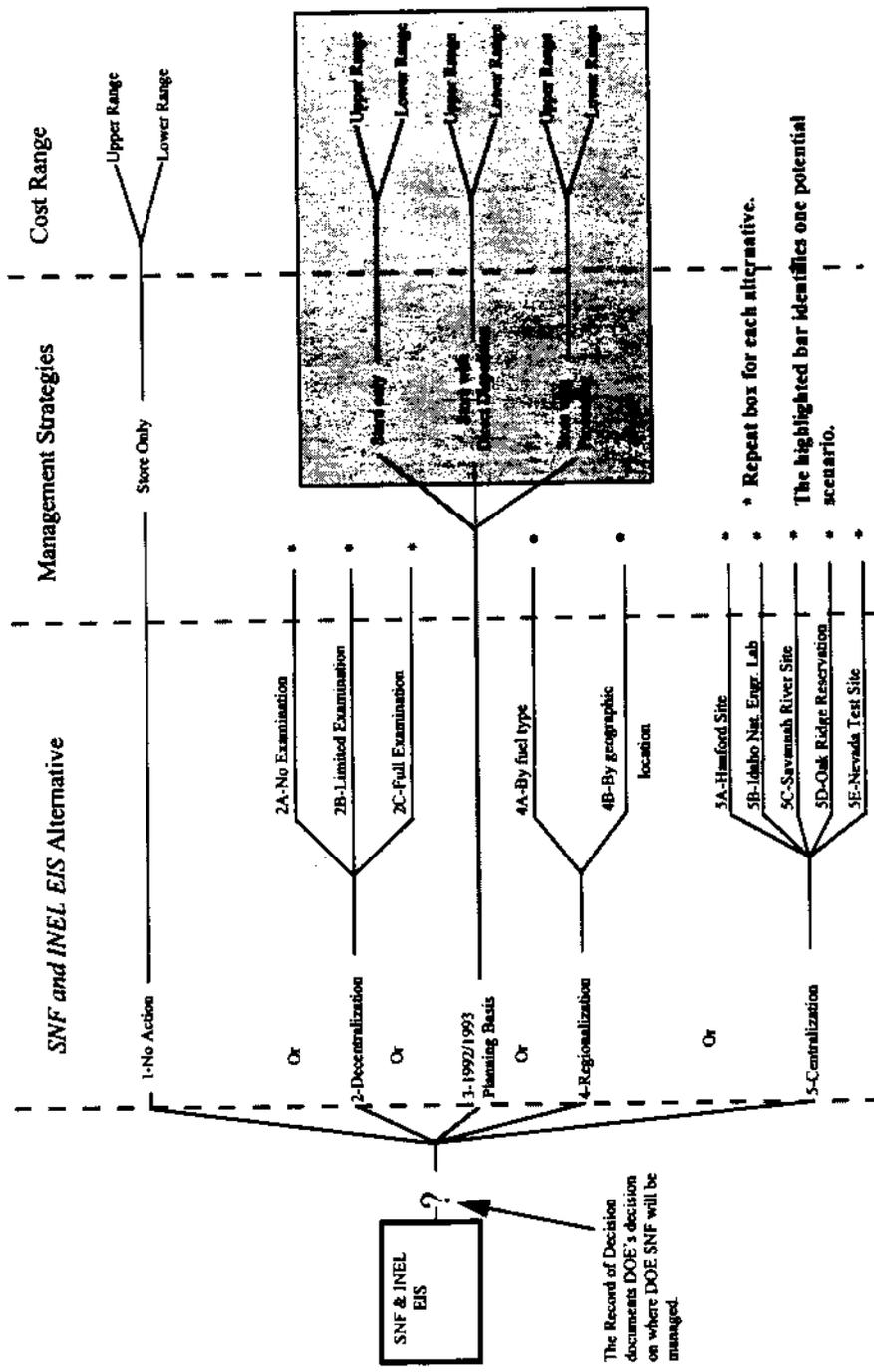


Figure 3-1. Scenarios: Relationship of Alternatives, Strategies, and Cost.

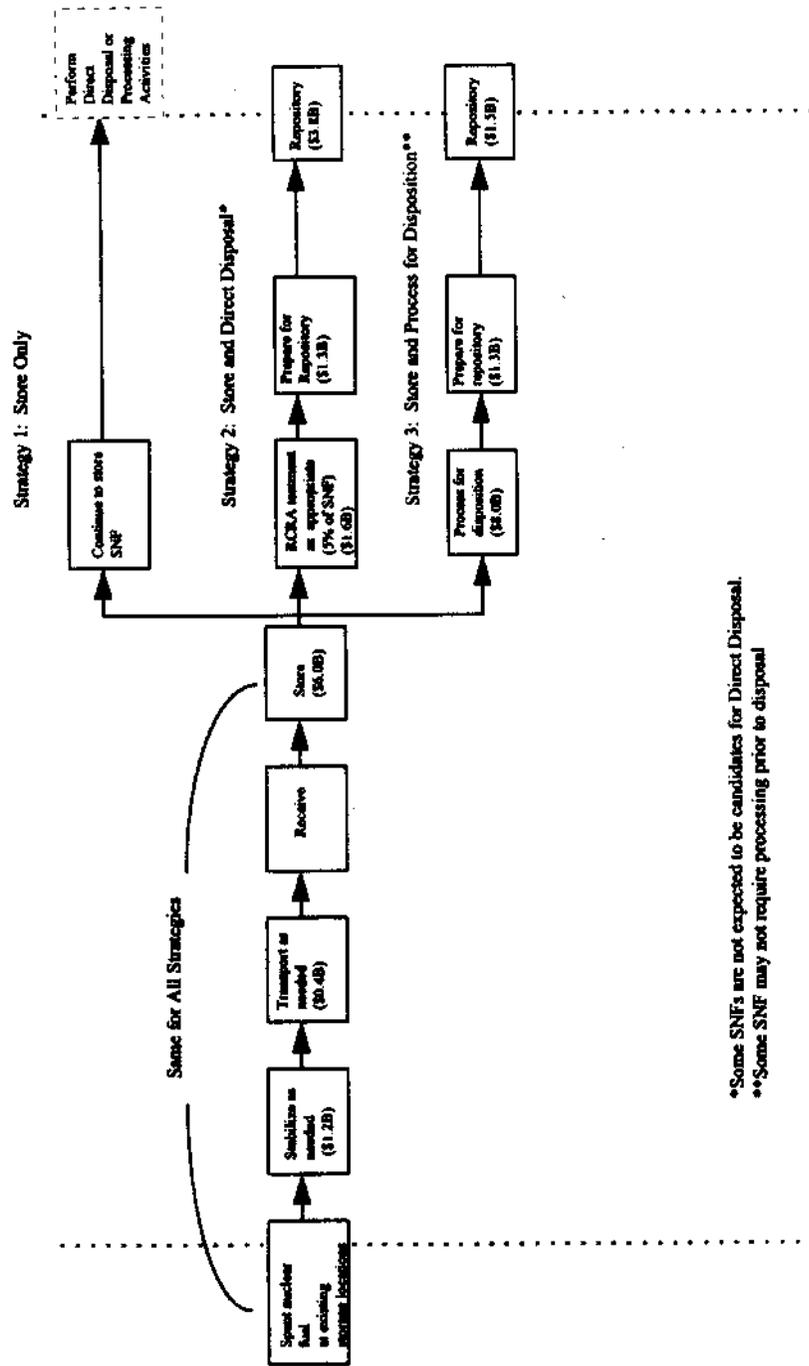


Figure 3-2. Overview of postulated strategies for managing SNF with costs for a "green field" centralization situation.

designs used to implement the technologies. This evaluation focuses on a single representative technology basis for each SNF management strategy and considers a range only when it could affect the selection of alternatives.

3.2.1 Storage Only

The Storage Only strategy provides for storage of DOE SNF at a location(s) for up to 40 years. Under this strategy, the SNF will be stabilized, transported, stored, and monitored as needed for safety considerations, but no other actions would be taken toward ultimate disposition. The generic facilities and activities for the Storage Only strategy are summarized in Appendix A. There would be transition periods for most alternatives during which the SNF would be moved from some existing storage facilities to either another existing facility or a new facility. The existing facilities with a useful life expectancy sufficient for use beyond this transition period are identified in Appendix B.

3.2.2 Direct Disposal

The Direct Disposal strategy provides for safe SNF storage plus preparation and direct disposal in a geologic repository to be developed by DOE's Office of Civilian Radioactive Waste Management (OCRWM). The preparation indicated in Figure 3-2 would involve packaging the SNF in canisters but would not include modifying the fuel matrix through processing, except for treatment of hazardous characteristics applicable to RCRA (Upper Range only). Actions related to this packaging include procuring the canisters and overpacks for disposal, along with characterizing and certifying the SNF. Appendix A describes the facilities required for preparation. Expenses associated with placement of DOE SNF in the repository (including transportation, repository development and evaluation, and on-site repository expenses) were also included in this strategy. Note that not all fuels may be acceptable for Direct Disposal and that no decision has been made regarding disposal of high-enriched uranium and plutonium-based SNF. Appendix F contains supporting data on repository expenses.

3.2.3 Processing

The Processing strategy provides for safe SNF storage until the SNF is processed and the resulting high-level radioactive waste is immobilized and placed into a geologic repository. Although DOE phased out reprocessing of SNF for purposes of uranium recovery, DOE policy does not preclude processing for waste management purposes (i.e., immobilization and volume reduction), which is the purpose of the processing discussed herein. While there are many candidate processes, this evaluation is generally limited to the historic aqueous processing technologies. Aqueous processes (that is, those that chemically dissolve and separate uranium) were selected for the following reasons:

- Extensive data are available for aqueous processing costs,
- Existing processing facilities are primarily based on aqueous processing, and
- Other processing technologies will likely require additional development and new facilities.

The evaluation of this strategy included costs associated with processing activities and disposition of the resulting materials, including high-level waste, low-level waste, and transuranic waste. Appendix A describes the generic facilities required for processing.

3.3 Cost Ranges

Use of existing facilities — A primary difference between the SNF management alternatives and between candidate sites is the potential use of existing facilities. Therefore, the cost evaluation considers Upper and Lower Cost Ranges based upon the maximum and minimum utilization of existing facilities.

RCRA Treatment — Because RCRA requirements could affect the relative ranking of alternatives due to the potential duplication of treatment facilities, the cost evaluation considers an Upper Cost Range with RCRA treatment and a Lower Cost Range without RCRA treatment. Duplication of treatment facilities would be required if potential RCRA SNF was not managed at a single site and treatment was required. Discussions are currently being held between DOE and the Environmental Protection Agency to determine whether SNF would be subject to management under RCRA if it were declared a waste.

3.4 Scenarios

To analyze costs involved with future actions for managing DOE SNF, scenarios were developed to describe various possible management schemes. A scenario describes SNF management for one alternative, under one of the three strategies, and for one cost range. The major alternatives (11 total) for the Decentralization, 1992-1993 Planning Basis, Regionalization, and Centralization alternatives resulted in a total of 66 scenarios; the No Action alternative added two more scenarios (No Action only analyzed for Storage Only strategy).

This cost evaluation did not attempt to evaluate all potential SNF management strategies since they cannot be anticipated on a programmatic basis and most will not affect the relative cost ranking of alternatives. The discussion of uncertainty (Section 7) and the sensitivity analysis (Section 8) provide further insight into these parameter variations.

Table 3-1. Locations of Spent Nuclear Fuel Management by EIS Alternative

SNF & INEL EIS Alternatives		SNF Management Locations
1	No Action	ANL-E, BNL, B&W, FRR, FSVR, Hanford, INEL, LANL, NNPP, Non-DOE, ORR, SNL, SRS, WVDP
2	Decentralization	ANL-E, BNL, Hanford, INEL, LANL, NNPP, ORR, SNL, SRS, WVDP
3	1992/1993 Planning Basis	Hanford, INEL, SRS
4A	Regionalization by Fuel Type	Hanford, INEL, SRS
4B	Regionalization by Geography	INEL, SRS ¹
5A	Centralization at Hanford	Hanford
5B	Centralization at INEL	INEL
5C	Centralization at SRS	SRS
5D	Centralization at ORR	ORR
5E	Centralization at NTS	NTS

Table Acronyms:

ANL-E	Argonne National Laboratory - East
BNL	Brookhaven National Laboratory
B&W	Babcock and Wilcox in Lynchburg
FRR	Foreign Research Reactor Sites (approximately 42 countries)
FSVR	Fort St. Vrain Reactor Site
Hanford	Hanford Site
INEL	Idaho National Engineering Laboratory (as used here, INEL includes ANL-W and NRF)
LANL	Los Alamos National Laboratory
NNPP	Naval Nuclear Propulsion Program (Kesselring Site, and Norfolk, Pearl Harbor, Portsmouth, and Puget Sound Naval Shipyards)
Non-DOE	44 Non-DOE domestic research and test reactors including universities, non-DOE government agencies, and companies
NTS	Nevada Test Site
ORR	Oak Ridge Reservation
SNL	Sandia National Laboratory
SRS	Savannah River Site
WVDP	West Valley Demonstration Project

¹Other combinations for geographical regionalization exist beyond this combination. These combinations were found to cost a minimum of \$1B more and are not addressed herein.

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4. COST EVALUATION ASSUMPTIONS

Many assumptions were used in the cost evaluation to provide a common basis. The assumptions presented in this section do not represent current DOE policy; rather, they provided a basis to perform the cost evaluation. Many of the assumptions address issues for which DOE will make decisions in the future.

1. **Under the No Action alternative, existing SNF facilities (or currently planned facilities) will be used exclusively for the entire 40-year period at all sites.**

Discussion — The SNF & INEL EIS definition of the No Action Alternative involves “minimum actions required for safe and secure management of SNF at or close to the generation site or current storage location.” Under No Action, as described in the SNF & INEL EIS, the Navy procures approximately 500 shipping containers for storage, but the only construction of new facilities is a concrete pad at INEL for the Three Mile Island-2 core debris. Though not in the draft SNF & INEL EIS, new storage of N-Reactor fuel at Hanford is also planned and included in the cost evaluation. Future safety concerns with No Action may not be adequately resolved without construction of additional new facilities.

Facilities to prepare all DOE SNF for disposition do not currently exist. The limitation on construction of new facilities under the No Action alternative delays actions—and associated costs—for the ultimate disposition of DOE SNF until after 2035.

2. **The cost evaluation considers all sites included in the SNF & INEL EIS for Decentralization (ANL-E, BNL, Hanford, INEL, LANL, SNL, ORR, SRS, WVDP, FSVR, and the five shipyard/prototype locations, Kesselring Site, and Norfolk, Pearl Harbor, Portsmouth, and Puget Sound Naval Shipyards). These sites are evaluated for the Storage Only, Direct Disposal, and Processing strategies, with the exception that Navy SNF is assumed to be shipped to a DOE site for any required Direct Disposal or Processing functions.**

Discussion — This cost evaluation includes cost data for life-cycle SNF management at all candidate sites under Decentralization to provide insight into the real cost associated with managing at multiple locations. While it may not be reasonable to build, operate, and decontaminate and decommission (D&D) new facilities to prepare SNF for Direct Disposal or to process it at locations with minor SNF quantities, it is important to evaluate the cost implications of managing SNF in a decentralized manner.

- 3. For Regionalization by Geography (Alternative 4B), the only site option to be considered in this evaluation is the INEL and SRS combination.**

Discussion — There are ten options in the SNF & INEL EIS under Alternative 4B, reflecting combinations of the five candidate sites. These ten options would result in 60 scenarios reflecting the three strategies and two cost ranges, almost doubling the number evaluated. This evaluation only considers the INEL and SRS combination because it was found to be the least expensive option. INEL is the least costly western site because of its existing storage capability that could likely be used through 2035 and because it is the current site of the Expanded Core Facility (ECF). SRS is the least costly eastern site because most eastern SNF is currently managed at the SRS, which has existing SNF management capacity that may be utilized—the estimated cost to manage this SNF at the Oak Ridge Reservation exceeds the cost to keep it at the SRS.

- 4. Future Costs associated with correcting identified SNF storage vulnerabilities as identified in the vulnerability assessment (Reference 3) are included in this cost evaluation.**

Discussion — Costs associated with correction of vulnerabilities DOE identified in its SNF storage facilities are part of the cost of SNF management and included in the cost evaluation. New SNF storage at Hanford is included under the No Action scenarios.

- 5. A portion of DOE SNF may fall under RCRA regulations, and appropriate treatment provisions will be provided.**

Discussion — Based on ongoing process knowledge evaluations, some portion of DOE's SNF may fall under RCRA. DOE has initiated discussion with the U.S. Environmental Protection Agency on the potential applicability of the RCRA to SNF. Further discussions with U.S. Environmental Protection Agency Headquarters and regional offices and state regulators are ongoing to develop a path forward toward meeting any RCRA requirements that may apply. For this evaluation, costs for management of the affected SNF types as RCRA material were included in the upper cost range for the Direct Disposal strategy. Under the Lower Cost Range, no RCRA treatment was assumed.

- 6. SNF transportation requirements (Reference 5) for each alternative are the same as those used for the SNF & INEL EIS**

Discussion — This is the transportation basis used for the SNF & INEL EIS, and it is appropriate for use in this evaluation as well.

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- 7. Transportation costs associated with shipments of SNF to the locations specified in the alternatives will occur uniformly over a 15-year period.**

Discussion — The actual time in which transportation of SNF will occur varies from alternative to alternative. This simplifying assumption is acceptable because:

- *transportation costs (as shown in this cost evaluation) are not a dominant factor in overall SNF management costs, and the time period over which the costs are spread is not crucial, and*
- *shipping schedules are not known and fifteen years is a reasonable mid-range time period.*

- 8. The inflation rate and nominal interest rate for the period of consideration will be projected in Office of Management and Budget Circular A94 (Reference 6). Results are presented in terms of constant 1995 dollars and net present value (NPV), which factors in interest (discount rate, 7.1%) and inflation (3.2%).**

Discussion — OMB Circular A94 provides interest and inflation rate guidance to be used by government organizations for this type of cost evaluation. The reporting of costs in constant-year dollars and net present value allows both perspectives to be considered.

- 9. Generic facility cost estimates are appropriate for all new facilities under the alternatives. Site-specific cost estimates are developed by scaling the generic facility costs for each scenario.**

Discussion — Use of generic facility data is appropriate because it allows comparison of sites on a consistent basis even if estimated costs over- or under-represent actual costs.

- 10. This cost evaluation uses a scaling exponent of 0.3 to adjust facility capital and O&M costs for different capacities.**

Discussion — Scaling factors used in the chemical process industry were analyzed for applicability to SNF management facilities. It was concluded that development of scaling exponents (see Appendix C) specifically for SNF management was the appropriate course. The 0.3 exponent was considered appropriate based on:

- *cost estimates for two SNF monitored retrievable storage complexes with different capacities,*
- *cost comparisons for SNF processing facilities with differing capacities, and*
- *cost estimates developed for DOE radioactive waste treatment facilities.*

11. The following assumptions apply for existing facilities:

- **Under the Lower Cost Range scenario, existing facilities are not assumed to be upgraded to meet the requirements of the latest revision to DOE Order 6430.1A [General Design Criteria (Reference 7)] and other DOE Orders (5480 series). However, some maintenance-type improvements are considered in the Lower Cost Range scenarios. Any facility upgrades are bounded by the Upper Cost Range, where construction of new facilities is generally assumed. Cost estimates are based on the use of the existing facilities identified in the Appendix B.**
- *D&D costs for contaminated existing facilities are considered to be sunk costs outside the scope of this analysis.*
- *Historic facility O&M costs provide a reasonable forecast of future costs for existing facilities.*

Discussion — The assumptions related to existing facilities define costs associated with using these facilities in implementing the postulated scenarios. Continued operation of these existing facilities without major refurbishment represents the Lower Cost Range. Replacement of non-compliant facilities represents the Upper Cost Range.

D&D costs for existing contaminated facilities were not included in this analysis, because such costs will be required regardless of whether an existing facility is used in implementing one of the postulated strategies. However, D&D costs for those existing facilities not previously contaminated were included, because they would be a direct result of implementing a strategy.

Historic costs are the best available estimate of future O&M costs for existing facilities, even though there may be some site-specific differences in accounting practices. It is highly speculative to adjust these historic costs in anticipation of future requirements.

12. For the alternatives requiring construction of a new naval fuel examination facility, the new facility cost is based on the design of the existing ECF (See Appendix D of the SNF & INEL EIS).

Discussion — Since cost estimates are available for construction of a new ECF, and since major changes in design are not anticipated, estimates here are based on a duplication of the existing ECF whenever a strategy calls for a new naval fuel examination facility.

13. D&D costs are included for new facilities supporting SNF management.

Discussion — DOE Order 5700.2D (Reference 8) requires that D&D costs be considered for cost estimates on new projects. However, D&D of existing facilities is considered a sunk cost outside the scope of current decisions.

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Estimates of D&D costs for existing facilities were considered in the sensitivity analysis, but they are not directly part of the evaluation.

- 14. For all alternatives, N-Reactor SNF is placed into new wet storage. For all alternatives except No Action, it is also stabilized and transitioned to dry storage.**

Discussion — This assumption is consistent with the current plan for correction of the K-Basin vulnerabilities and stabilization of the N-Reactor SNF. N-Reactor fuel is managed at Hanford for all scenarios, except under Regionalization (4B) or Centralization (B, C, D, E) alternatives at a site other than Hanford.

- 15. Dry storage of aluminum SNF can occur safely through 2035.**

Discussion — While DOE has not demonstrated safe dry storage of aluminum SNF, foreign experience and expert opinion indicate it is a reasonable expectation if the SNF is properly prepared. If a fuel cannot be safely stored through 2035, then it will be processed. The processing of aluminum SNF is already addressed as one of the SNF management strategies.

- 16. A geologic repository will be available for the postulated Direct Disposal strategy and for the disposal of high-level waste from the postulated Processing strategy.**

Discussion — The only disposition cost data available are associated with a geologic repository being developed by the DOE Office of Civilian Radioactive Waste Management.

- 17. For the Processing and Direct Disposal strategies, all SNF and resulting high-level waste will be ready for disposition on or before 2035.**

Discussion — This amount of time may be required to make and implement a decision on the ultimate disposition of SNF.

- 18. The repository is a "hot" repository (i.e., can contain SNF with a cladding temperature of ~350°C).**

Discussion — For a "hot" repository (one with a high thermal loading density), decay heat criteria are not expected to be limiting factors for multipurpose container (MPC) loading of DOE SNF under the Direct Disposal strategy, based on the preliminary evaluation of several SNF types (Reference 9). The evaluation has not been performed for a "cold" repository, but the cost could be higher than for a "hot" repository.

- 19. For the Direct Disposal strategy, the repository will accept suitably packaged, high-enriched fuels.**

Discussion — This assumption is based on the premise that concerns about high-enriched uranium (e.g., criticality and safeguards) are resolved in a manner such that these fuels can be placed into a geologic repository.

- 20. The MPC concept currently being developed for commercial power reactor SNF (Reference 10) meets repository criteria and can be used for DOE SNF under the Direct Disposal strategy.**

Discussion — The Direct Disposal evaluation relies heavily on the commercial power reactor SNF MPC program as its foundation (see Appendix F). This is the best basis available at this time.

- 21. The container cost and repository expenses being considered for commercial SNF are valid for DOE SNF.**

Discussion — This cost evaluation is directed at providing relative cost information, and is not intended to support programmatic decisions such as the type of container to be used for DOE SNF disposal. This assumption allowed the cost evaluation to take advantage of existing studies on repositories and MPCs without biasing the container-selection process.

- 22. Under the Direct Disposal strategy, DOE will use the Boiling Water Reactor or Pressurized Water Reactor MPC baskets. Where SNF will not readily fit into these baskets (e.g., for Fort St. Vrain SNF), special baskets may be used. A unique basket may be used for Navy SNF.**

Discussion — Designing, licensing, and procuring unique baskets for DOE SNF is not considered cost-effective because there are over one hundred different DOE SNF types. A unique basket for Navy fuel would be expected to be cost-effective.

- 23. Under the Direct Disposal strategy, SNF is loaded into MPCs up to the volumetric limit of the MPC. Under the Upper Cost Range, all SNF exhibiting hazardous characteristics subject to RCRA is treated to remove the characteristics. Under the Lower Cost Range, there are no constraints associated with gas generation, pyrophoric behavior, water content, or cladding integrity.**

Discussion — The ability of the repository to accept high-enriched uranium SNF and the limits placed on its disposal are speculative at this time. Applying costs for low fissile loadings to high-enriched SNF would overwhelm the other uncertainties and considerations. Therefore, the high-enriched SNF is loaded into MPCs only on the basis of dimensional constraints. While this assumption has a very large potential impact on the overall costs, it does not affect the relative ranking of alternatives.

Treatment of SNF exhibiting hazardous characteristics subject to RCRA is included in the Upper Cost Range. It is assumed that molten salt electro-refining will be used for sodium-bonded SNF to remove the RCRA characteristic. Graphite SNF is assumed to be treated by burning the graphite and carbide. Because DOE SNF may be excluded from the requirements of RCRA, RCRA treatment is excluded from the Lower Cost Range.

- 24. All aluminum SNF and other low-integrity cladding SNF is placed into sealed, small dry cans prior to loading into MPCs for the Direct Disposal strategy. These cans serve as the primary fission product boundary.**

Discussion — This basis was used for the preliminary MPC conceptual design effort (Reference 7). Use of small cans currently appears to be a reasonable solution to cladding degradation problems.

- 25. SNF characterization will be performed prior to MPC loading. Once welded shut, the MPCs will not need to be opened for characterization or verification (including requirements of the International Atomic Energy Agency).**

Discussion — It is reasonable to assume that MPCs will not be loaded until preliminary acceptance criteria and characterization requirements are available. Any future need to open MPCs is speculative.

- 26. Under the Processing strategy, O&M costs, capital costs, and D&D costs associated with high-level radioactive waste resulting from future SNF processing at Hanford, INEL, and SRS are treated on an incremental basis.**

Discussion — High-level radioactive waste immobilization facilities are assumed to be required at these sites to immobilize the wastes already at the sites. Therefore, incremental costs (over and above planned costs for the original mission) associated with these SNF management support activities was appropriate.

- 27. Under the Processing strategy, uranium is separated via aqueous processing, with high-enriched uranium blended down to a low enrichment (< 20%) prior to separation. No cost credit is given for potential reuse of separated uranium.**

Discussion — The re-use of separated uranium is compatible with DOE's recent purchase and blending of Russian high-enriched uranium with subsequent potential sale on the open market for use in power production. The value of the uranium that could be recovered from DOE SNF is estimated to be \$2B, however, there are a number of potential reasons that may preclude the use of this uranium, including handling problems from high radiation fields (e.g., ^{232}U decay products), and reduced neutronic efficiency (due to higher ^{236}U concentrations). Potential uses and salvage values for plutonium are speculative and are not included.

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5. APPROACH

This section describes the methodology used in the development of relative costs for the SNF alternatives analyzed for this Cost Report.

5.1 Identify Generic Activities and Facilities Required

For purposes of this cost evaluation, DOE has identified generic activities and facilities required to accomplish each of the three management strategies, including stabilization, transportation, receipt, storage, and preparation of SNF for a repository. There are a number of ways to accomplish the overall objective (e.g., use of different storage technologies), and it is necessary to select one method for comparison purposes. The activities for each management strategy are generally identified in Figure 3-2, and more detailed information on each of the activities and the associated generic facilities is presented in Appendix A.

5.2 Develop Generic Cost Data

Planning cost estimates and schedules were derived for each generic facility and activity without development of conceptual designs specifically for this evaluation. The estimates were developed by first identifying the best available designs for similar facilities. Designs from previous DOE projects, such as the New Production Reactor project, were available for nearly all facilities. The capacity of the available designs were then compared to the requirements for management of DOE SNF. Adjustments to the available designs (e.g., addition of more modules) were made in those cases where necessary. Cost estimates were then developed for each of these generic facilities.

These cost estimates, as well as schedules, were based on recent DOE construction of remotely operated, heavily shielded facilities. The schedules and costs are summarized in Appendix A. These costs and schedules may be greater than those expected for the private sector.

5.3 Define Site Requirements and Scenarios

The SNF alternatives describe different quantities of each fuel type at each site. The different fuel types to be managed dictate that different activities and facilities would be required at the alternative site(s) selected for managing DOE's SNF. Similarly, because of differing fuel types and facility requirements, the costs for implementing each management strategy will vary from site to site.

There are several ways to quantify the SNF to be located at the various sites, for example, metric tons of heavy metal (amount of uranium, plutonium, and thorium), cladding types (encapsulation of the fuel, typically aluminum, zirconium, or stainless steel), enrichment (percentage of ^{235}U), and volume. The various characteristics of SNF affect facility requirements for storing, handling, and processing. For this cost evaluation, the number of MPCs is used as

the basis for cost allocation under the strategies of Storage Only and Direct Disposal. For the Processing strategy and high-level waste disposition in a geologic repository, metric tons of heavy metal define facility requirements and associated costs. The site-specific facility capacity requirements are summarized in Appendix D.

5.4 Develop Scaling Exponents

The SNF management scenarios consider construction of a number of new facilities with varying capacity requirements and, therefore, of varying costs. To develop cost estimates for these similar facilities with different capacities, a common industry approach called "scaling" was applied. Scaling allows for the development of planning cost estimates for facilities with different capacities using a known facility cost as a basis. Appendix C provides a detailed discussion of the scaling methodology used. This cost evaluation uses a scaling exponent of 0.3 to adjust facility capital and O&M costs for different capacities.

5.5 Existing Facility Capabilities

For this cost evaluation, the existing facilities assumed to continue operation during the interim 40-year period were identified (see Appendix B). The facilities listed in Appendix B are included in the Lower Cost Ranges even if they may not fully comply with modern design criteria (see Reference 4). The Upper Cost Range assumes that only existing facilities (except for the ECF at the INEL) in full compliance with modern design standards will be used. This assumption reduces the number of useful existing facilities.

5.6 Develop Spreadsheet

A spreadsheet was developed to perform the computations, to facilitate the integration of the large amount of data involved in the evaluation, and to allow for easy revision and limited consideration of "what if" cases. The spreadsheet was designed to account for the following factors:

- **Site-specific costs** - all SNF management sites being considered in the *SNF & INEL EIS*, the Naval Nuclear Propulsion Program sites, and small DOE sites are explicitly modeled (Table 3-1).
- **Cost composition** - capital, O&M, D&D, and transportation costs are calculated separately.
- **Annual costs** - all costs are calculated on an annual basis.
- **Scenario totals** - the costs for all sites are totaled for each scenario.
- **Sensitivity** - the spreadsheet supports the sensitivity assessment, which determines if the results are affected by (sensitive to) changes in the primary input parameters.

5.7 Perform Spreadsheet Calculation

The calculation process involved the following steps:

- Scale generic facility cost estimates to meet site-specific and scenario-specific requirements,
- Credit sites for existing facilities, modified as appropriate for the scenario, and
- Total cost data for all sites.

Beginning with the site-specific requirements for each scenario, appropriate adjustments (scaling and credits for existing facilities) were made. The SNF to be managed at a site for most scenarios is less than the total amount on which the generic facilities are based. Therefore, the costs of the generic facilities were scaled (or adjusted) to reflect the quantity and types of SNF located at each site for the scenario being evaluated. Since some sites already have existing facilities that may meet their needs under a given scenario, the scaled generic facility costs were then credited for existing facilities. Appendix B identifies the existing facilities credited with appropriate adjustments for modification for each scenario. Costs were developed for SNF transportation and expected repository fees to provide a complete cost picture. Once the adjustments were completed, relative costs were summed for each of the scenarios.

5.8 Peer Reviews

Several in-process reviews were conducted for the data generated, assumptions, and consistencies.

- Generic facility data were independently reviewed, updated, and/or new estimates prepared as needed by the Cost Estimating Department of Lockheed Idaho Technologies (LITCO).
- The assumptions were reviewed and approved by both DOE and the DOE Headquarters management review group.
- The spreadsheet was reviewed extensively and independently by LITCO personnel to verify calculational and logical consistencies.
- The generic data used in the spreadsheet were reviewed by all sites collectively and site-specific data were reviewed via site visits. The site visits consisted of meetings to review the data and calculation sequences in the spreadsheet, verify the respective site input, and check for consistency with other sites.

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6. RESULTS

The costs for each alternative are presented for the Storage Only, Direct Disposal, and Processing strategies. The results are presented in constant-year dollar, NPV, and cash flow perspectives. Each perspective provides different insights into the comparison of alternatives.

- Constant-year dollars allow life-cycle costs to be compared without consideration of inflation or interest rates. In other words, the costs are in terms of current (1995) buying power.
- NPV allows the life-cycle costs to be compared with consideration of inflation and interest. NPV is typically used in industry for cost benefit analyses. However, since there is no income associated with safe management of SNF, the NPV results presented herein demonstrate that the delay of actions lowers overall cost.
- Cash flow allows alternatives to be compared in terms of the annual cash flow required for budget considerations. Cash flow is presented here in terms of constant-year dollars.

O&M costs dominate the total costs for all strategies. Figure 6-1 shows the cost breakdown for the Storage Only strategy, Upper Cost Range, averaged over all alternatives. O&M accounts for roughly 2/3 to 3/4 of the total costs across all alternatives, management strategies, and cost ranges. Therefore, Figure 6-1 is representative of all scenarios.

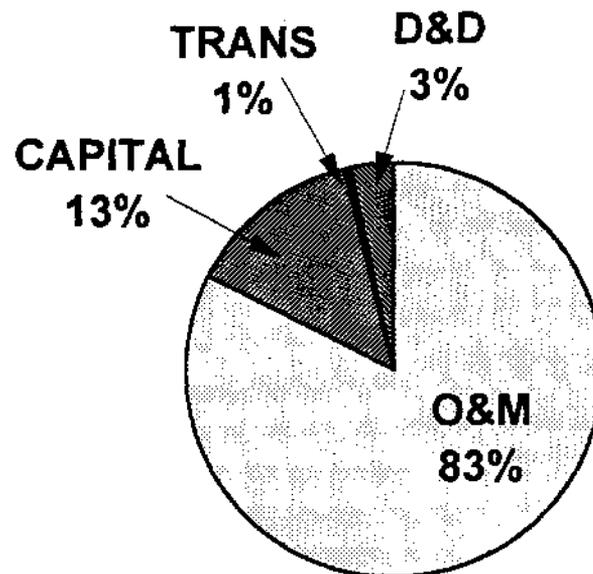


Figure 6-1. Cost Composition for Storage Only, Upper Cost Range.

6.1 Storage Only

The following sections present the cost comparison results for the Storage Only strategy (described in Section 3.2.1) from the perspective of constant-year dollar costs, NPV, and cash flow. This presentation allows for a direct cost comparison between the alternatives evaluated in the *SNF & INEL EIS*. Note: A disposition strategy would need to be implemented following this storage phase; hence, comparison of results for the Storage Only to those for the life-cycle strategies is inappropriate.

6.1.1 Constant-Year Dollars

Figure 6-2 displays a comparison of the alternatives for the Upper and Lower Cost Ranges for the Storage Only strategy based on constant-year dollars (1995). The range is smaller for the Centralization alternatives (5A through 5E) because mostly new facilities are used for both the Upper and Lower Cost Ranges.

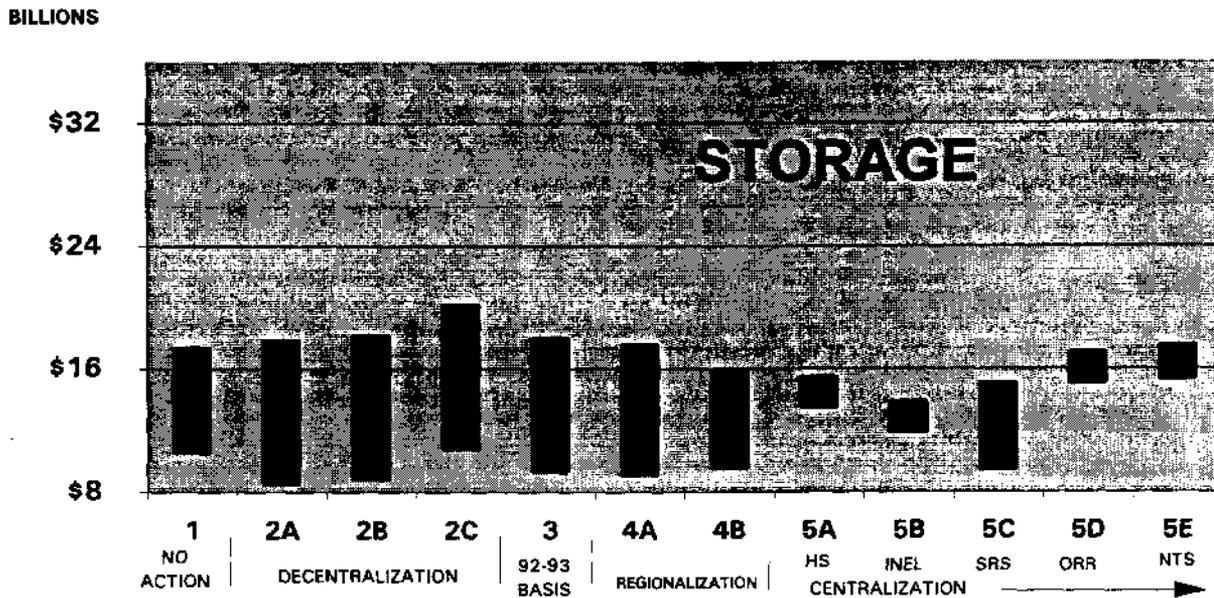


Figure 6-2. Constant Year Dollar (1995) Cost Ranges for Storage Only.

To simplify presentation of results, Figure 6-3 compares each alternative to the Planning Basis alternative. This reflects a baseline cost comparison for DOE's recent past SNF-management costs.

Upper Cost Range — Figure 6-3 shows that alternatives 1, 2A, 2B, or 4A are roughly equivalent to the Planning Basis because most SNF is located at the same sites (Hanford, INEL, and SRS) in each alternative. Regionalization 4B costs 11% less than the Planning Basis because all SNF is moved to two sites (INEL and SRS), which have existing SNF infrastructures, and economies of scale (it is more cost effective to build and operate one large facility than to build and operate several smaller facilities with the same combined capacity) dictate that two

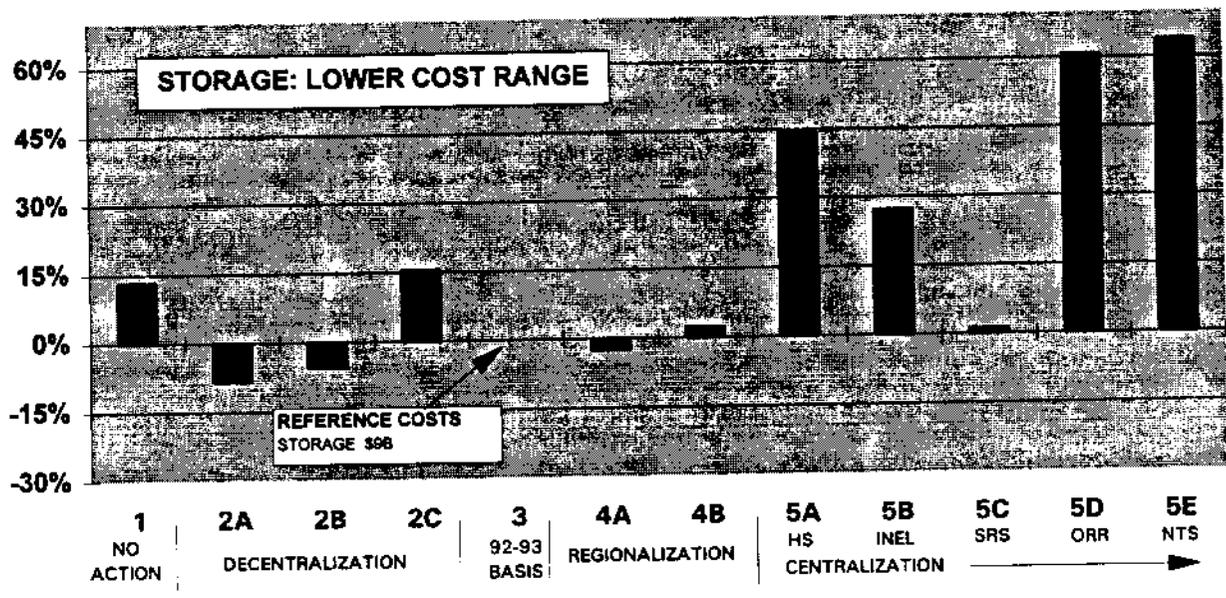
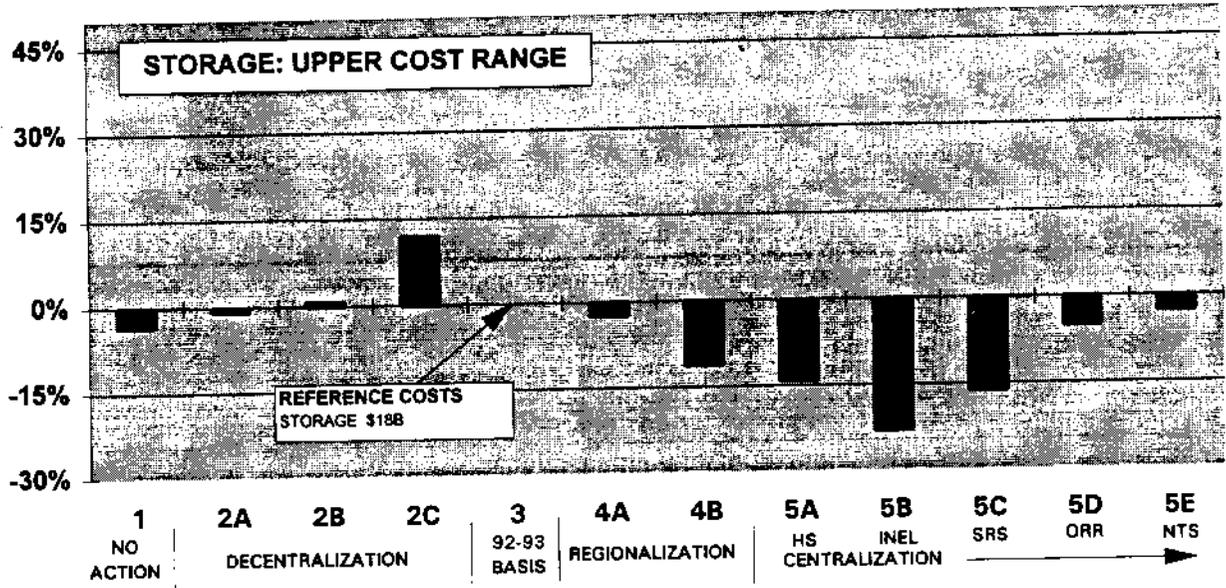


Figure 6-3. Storage Only: Comparison of alternatives to the 1992/93 Planning Basis for the Upper and Lower Cost Ranges.

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sites are less costly than three. Figure 6-3 also shows that if new facilities are built due to vulnerabilities or other considerations, it is least expensive to build all of the facilities at one site that currently has an existing SNF infrastructure (i.e., alternatives 5A, 5B, or 5C). In that case, the cost savings range from 14% to 23 % over the Planning Basis alternative. Centralization at sites with no SNF infrastructure, alternatives 5D and 5E, are roughly equivalent to the Planning Basis alternative.

Lower Cost Range — If existing facilities can continue to be used for the Storage Only strategy, then it is least expensive to manage fuel under alternatives that maximize use of sites with existing capabilities (i.e., alternatives 2A, 2B, 3, 4A, 4B, or 5C). The centralization alternatives, which would require new construction of storage facilities, cost 1% to 64% more than the Planning Basis. Centralization alternative 5C is roughly equivalent to the Planning Basis alternative because of the use of existing facilities at the Savannah River site with minimal upgrades.

Discussion — The expected costs would likely be somewhere in the middle where some existing facilities could continue to be utilized, at least for a limited time. In that case, the cost difference between alternatives that manage fuel at fewer sites (3, 4A, and 4B) would be negligible, given the degree of uncertainty for future actual costs (see Section 7).

6.1.2 Net Present Value

Figure 6-4 provides a comparison of the alternatives for the Upper and Lower Cost Ranges for the Storage Only strategy based on NPV. The pattern of results is very similar to those presented for the constant-year dollar basis, and the discussion in Section 6.1.1 applies for NPV as well.

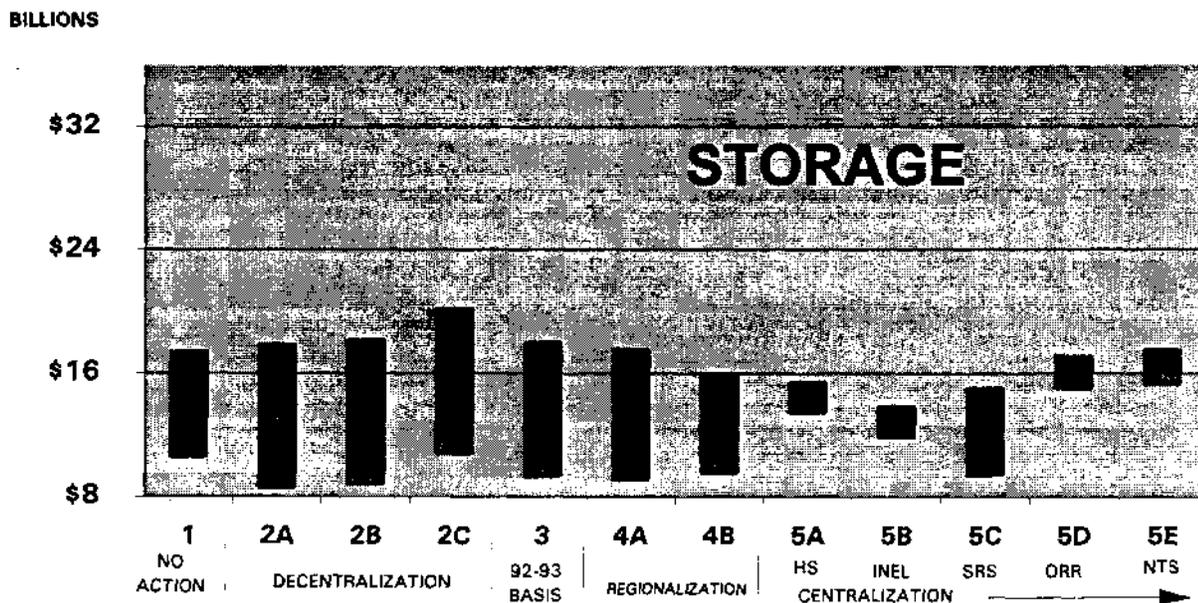


Figure 6-4. NPV Cost Ranges for Storage Only.

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6.1.3 Cash Flow

The annual cash flow for each alternative is presented in Figure 6-5. Since the schedules have not been optimized, five-year averages are presented here to smooth the cash flows. Alternatives 1, 3, 4A, and 4B are all comparable for both peak and average cash flows. While the peak flows for 5A, 5B and 5C are higher than the other alternatives due to construction of new facilities, the average cash flows are lower, as is the total cost for centralization over the 40-year storage period. Both peak and average cash flows are higher, as expected, for the three Decentralization alternatives and Centralization 5D and 5E, due to facility duplications from managing SNF in a decentralized manner (2A-C) and having to build SNF infrastructure (5D-E) at sites where it does not currently exist.

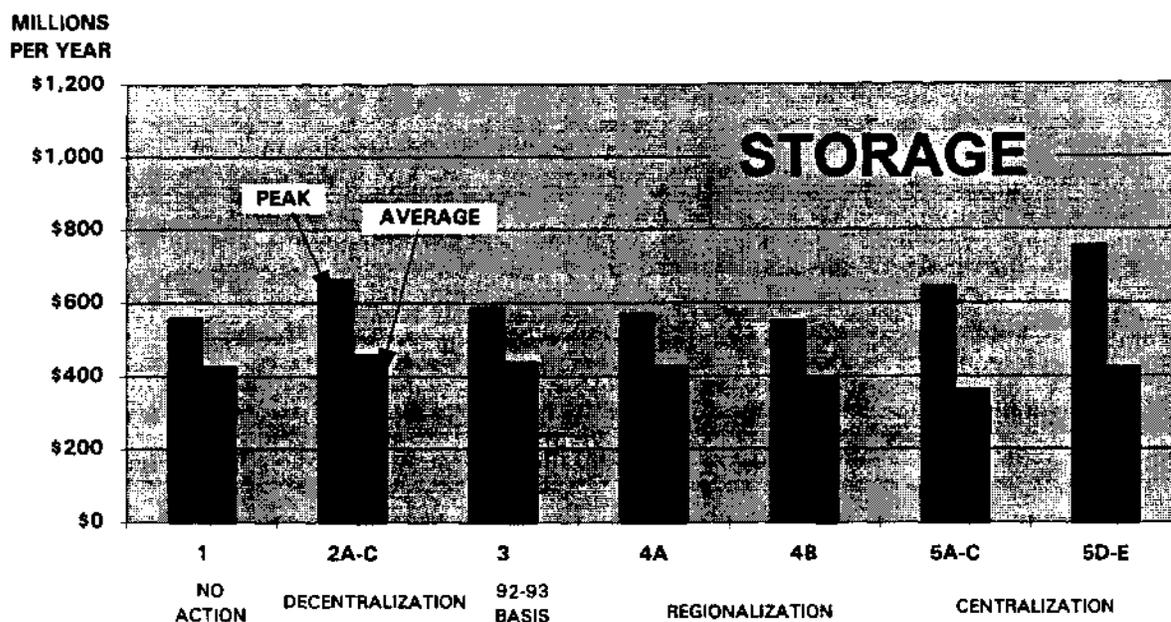


Figure 6-5. Cash Flow for Storage Only in constant year dollars.

6.2 Direct Disposal

This section presents a comparison of the alternatives for the Direct Disposal strategy, which is described in Section 3.2.2. The No Action alternative is not included under this strategy because, by definition, it is limited to the Storage Only strategy.

6.2.1 Constant-Year Dollars

Figure 6-6 provides a comparison of the alternatives for the Upper and Lower Cost Ranges for the Direct Disposal strategy based on constant-year dollars (1995). The range is smaller for the Centralization alternatives (5A through 5E) because mostly new facilities are used for both the Upper and Lower Cost Ranges.

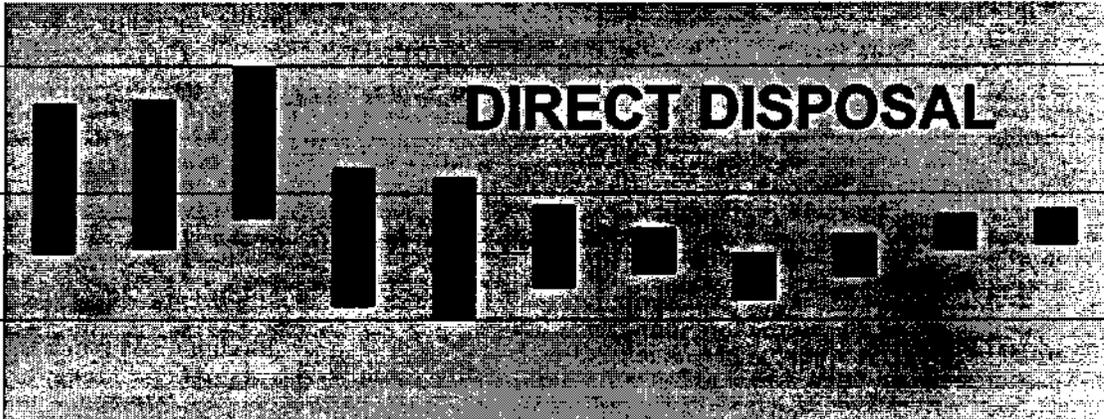
BILLIONS

\$32

\$24

\$16

DIRECT DISPOSAL



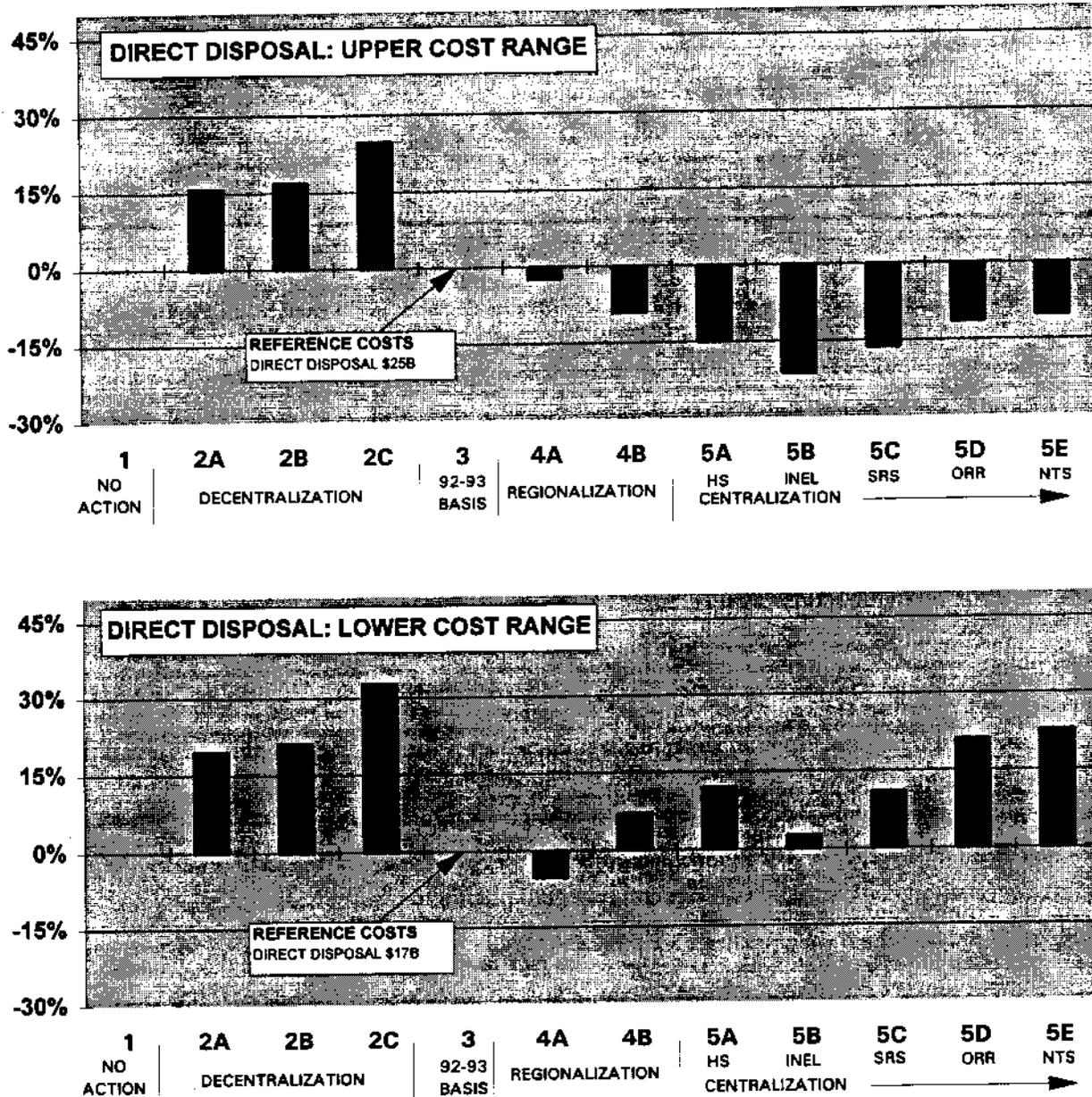


Figure 6-7. Direct Disposal: Comparison of alternatives to the 1992/93 Planning Basis for the Upper and Lower Cost Ranges.

Discussion — Overall, the Decentralization alternatives are more expensive for this strategy than any other alternatives because of the duplication of processing facilities that would be required. Centralization at Oak Ridge or the Nevada Test Site would also require a large amount of new construction. A scenario in which some existing facilities could continue to be utilized largely eliminates the cost difference between alternatives 3, 4A, 4B, 5A, 5B, and 5C, given the degree of uncertainty for future actual costs (see Section 7).

6.2.2 Net Present Value

Figure 6-8 provides a comparison of the alternatives for the Upper and Lower Cost Ranges for the Direct Disposal strategy based on NPV. The results are very similar to those presented for the constant-year dollar basis, and the discussion presented in Section 6.2.1 applies to NPV, as well.

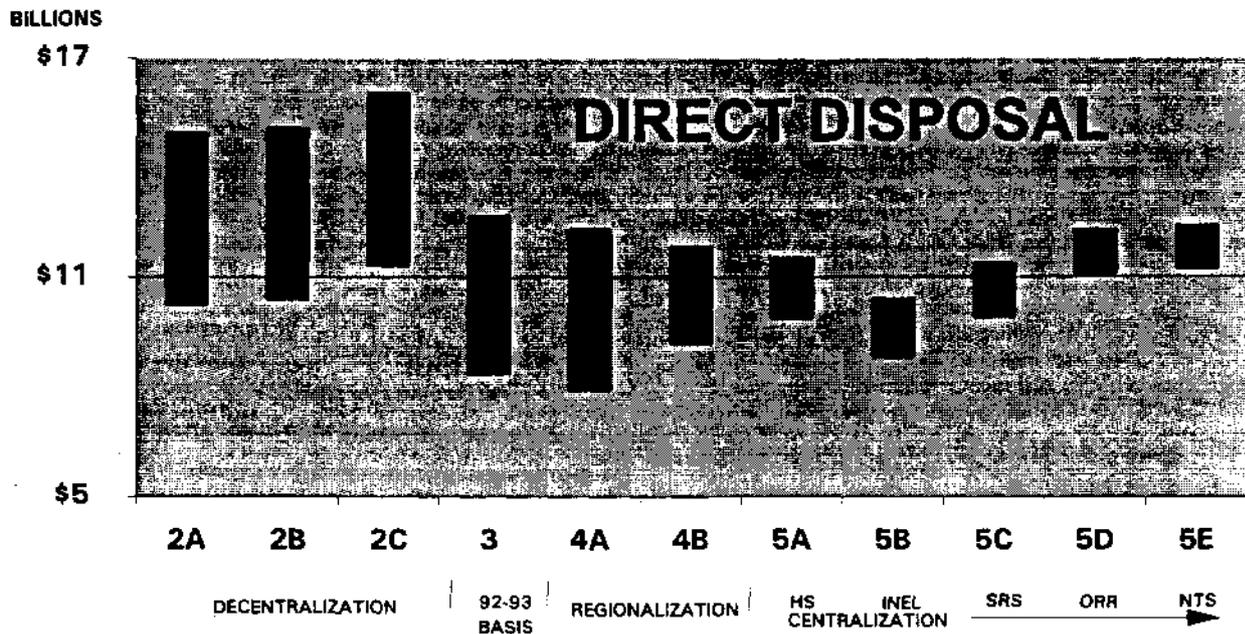


Figure 6-8. NPV Cost Ranges for Direct Disposal.

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6.2.3 Cash Flow

The annual cash flow for each alternative is presented in Figure 6-9. Since the schedules have not been optimized, five-year averages are presented here to smooth the cash flows. The pattern of results is consistent with the constant year dollars results. The alternatives with the highest total life-cycle costs also have the highest cash flows.

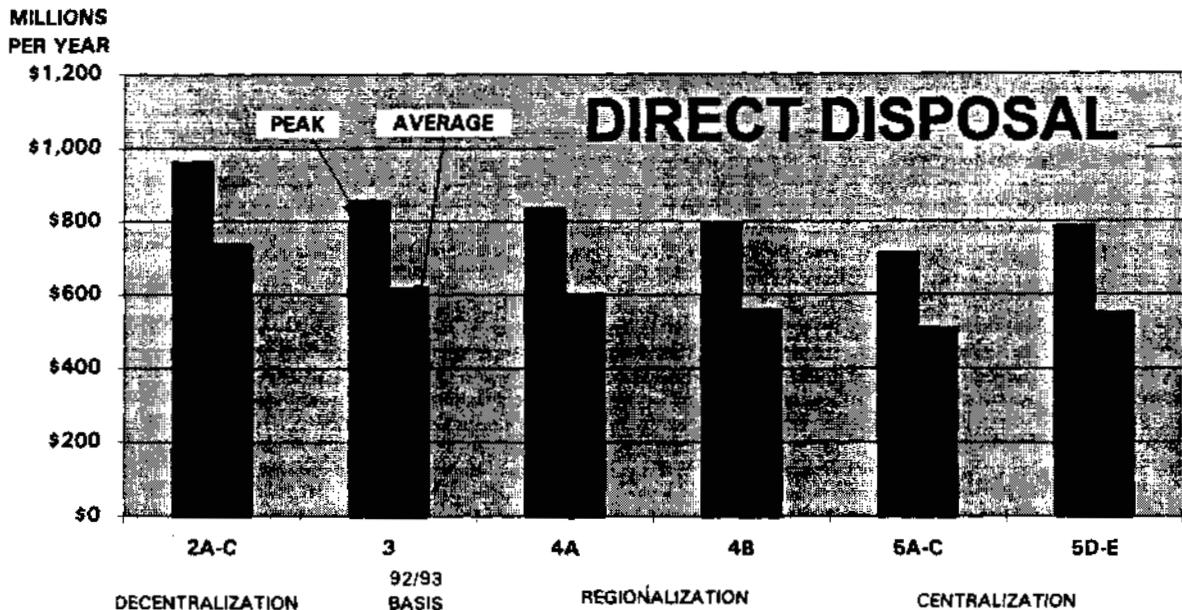


Figure 6-9. Cash Flow for Direct Disposal in constant year dollars.

6.3 Processing

This section presents a comparison of the alternatives for the Processing strategy, which is described in Section 3.2.3. The No Action alternative is not included under this strategy, because, by definition, it is limited to the Storage Only strategy.

6.3.1 Constant-Year Dollars

Figure 6-10 provides a comparison of the alternatives for the Upper and Lower Cost Ranges for the Processing strategy based on constant-year dollars (1995).

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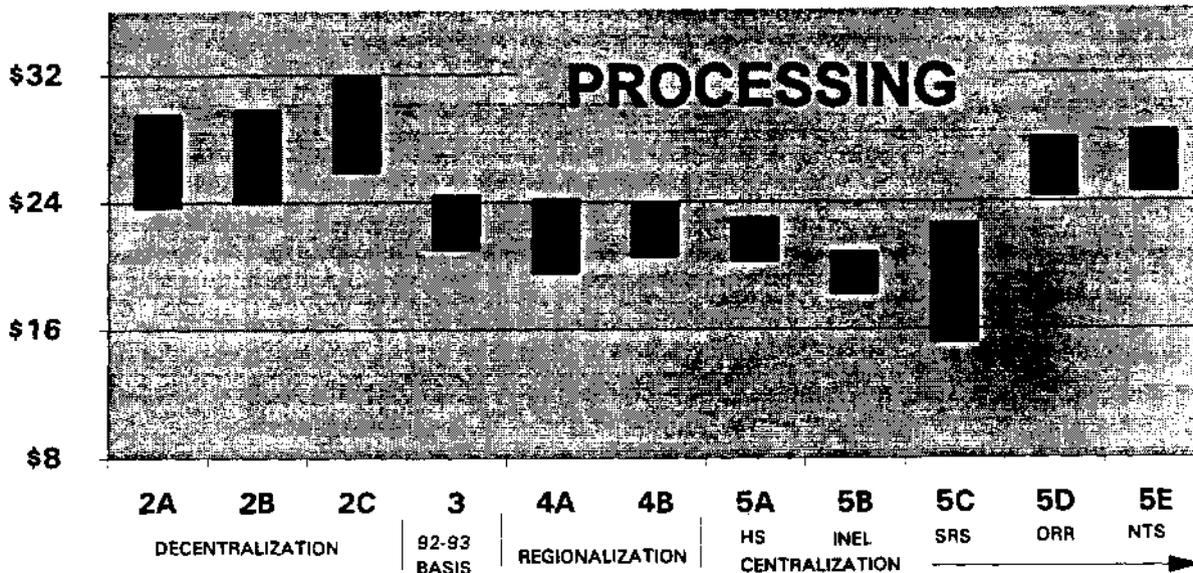


Figure 6-10. Constant Year Dollar (1995) Cost Ranges for Processing.

To simplify presentation of results, Figure 6-11 compares each alternative to the Planning Basis alternative. This reflects a baseline cost comparison for DOE's recent past SNF-management costs.

Upper Cost Range — Figure 6-11 shows that Decentralization 2A, 2B, and 2C are 21% to 30% more expensive than the Planning Basis. This result is directly related to performing costly processing functions requiring large capital investments at multiple sites. Regionalization by Fuel Type (4A) and Regionalization by Geography (4B, INEL and SRS) are less expensive than the Planning Basis because of economies of scale. Centralization 5A, 5B, and 5C are 6% to 15% less expensive than the Planning Basis alternative due to economies of scale (i.e., building and operating facilities in a consolidated manner). Centralization 5D and 5E are roughly 15% more expensive due to lack of existing SNF infrastructure at the Oak Ridge and Nevada sites.

Lower Cost Range — Once again, the graph shows that managing SNF at sites with existing facilities is generally less expensive. Centralization 5C costs 28% less than the Planning Basis because of the number of existing processing facilities that were assumed to be used with minimal upgrades.

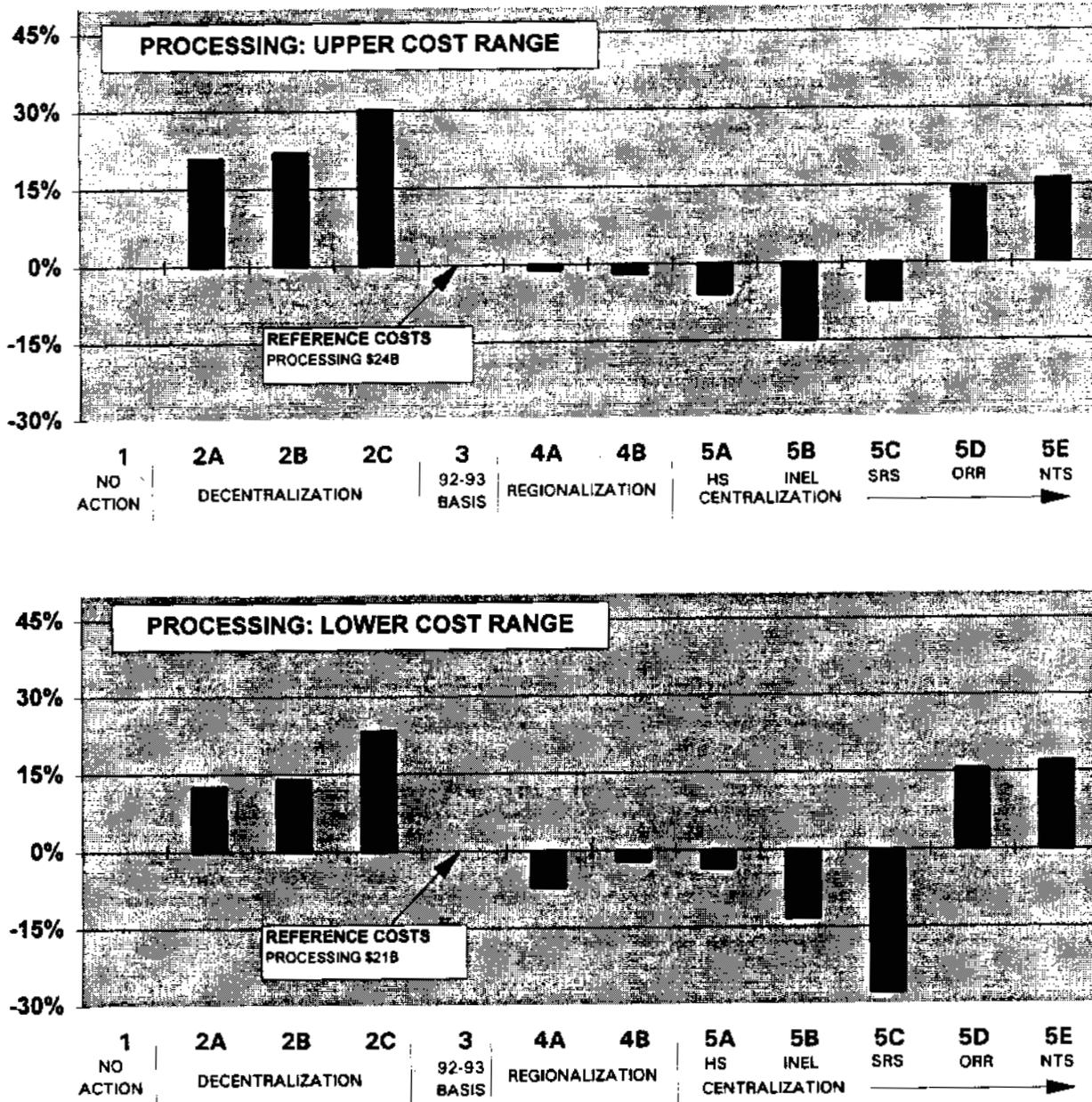


Figure 6-11. Processing: Comparison of alternatives to the 1992/93 Planning Basis for the Upper and Lower Cost Ranges.

Discussion — Overall, the Decentralization alternatives are vastly more expensive for this life-cycle strategies than any other alternatives because of the duplication of processing facilities that would be required. Centralization at Oak Ridge or the Nevada Test Site would also require a large amount of new construction. A scenario in which some existing facilities could continue to be utilized largely eliminates the cost difference between alternatives 3, 4A, 4B, 5A, 5B, and 5C, given the degree of uncertainty for future actual costs (see Section 7).

6.3.2 Net Present Value

Figure 6-12 provides a comparison of the alternatives for the Upper and Lower Cost Ranges for the Processing strategy based on NPV. The results are very similar to those presented on a constant-year dollar basis, and the discussion presented in Section 6.3.1 applies to NPV as well.

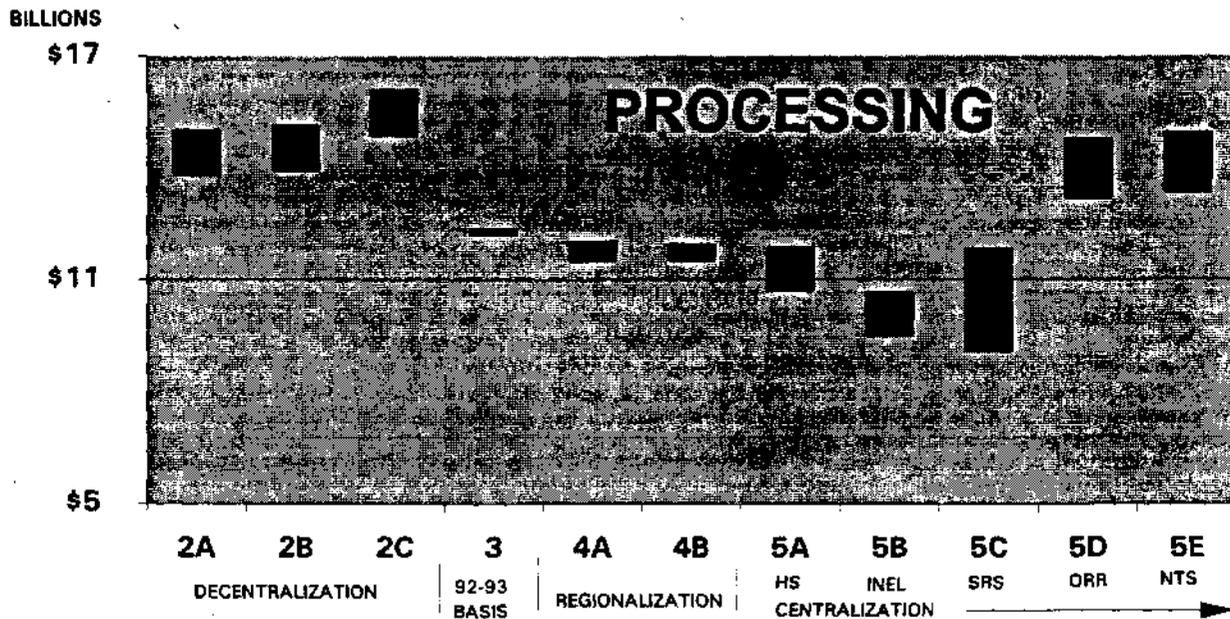


Figure 6-12. NPV Cost Ranges for Processing.

6.3.3 Cash Flow

The annual cash flow for each alternative is presented in Figure 6-13. Since the schedules have not been optimized, five-year averages are presented here to smooth the cash flows. The pattern of results is consistent with the constant year dollar results. The alternatives with the highest total costs also have the highest cash flows.

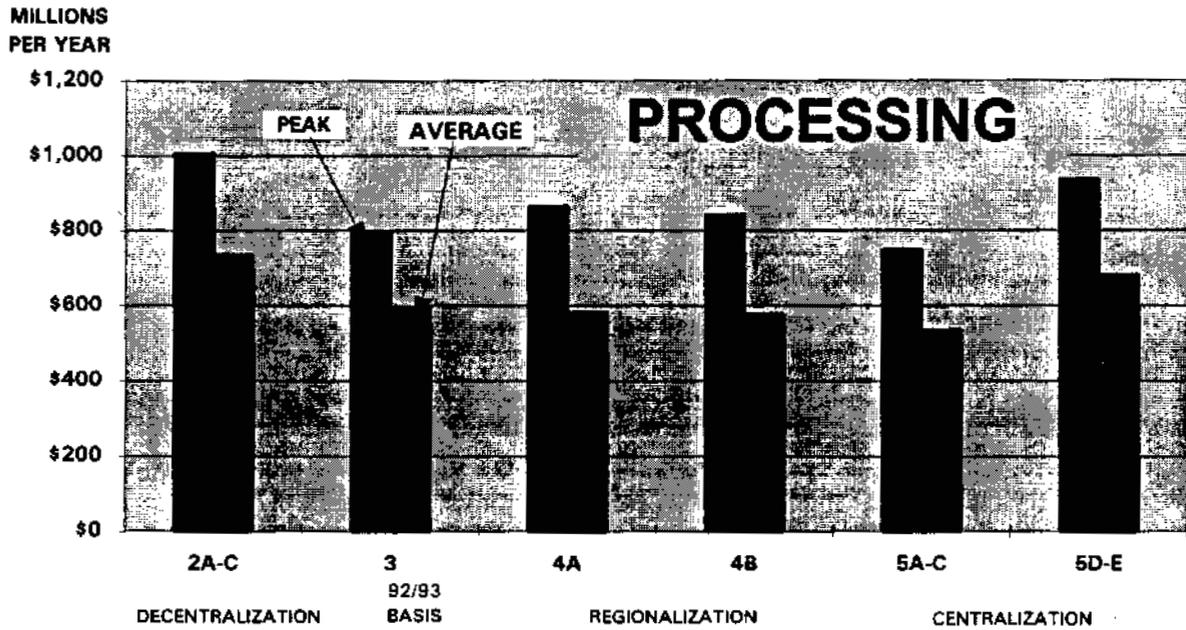


Figure 6-13. Cash Flow for Processing in constant year dollars.

6.4 Conclusions

The extent to which existing facilities are used is a primary variable that affect the costs of life-cycle management. If new facilities are required, it is least expensive to centralize and build at one site that has existing SNF infrastructure (i.e., 5A, 5B, 5C). The cost savings for all strategies result from economies of scale: It is more cost effective to build and operate one large facility than to build and operate several smaller facilities with the same combined capacity. These economies of scale for utilizing larger, co-located facilities more than offset increased transportation costs. Transportation costs, which are typically 1% of total costs, are not an overriding cost consideration in selection of locations for SNF management.

A scenario in which a significant number of existing facilities could be upgraded at low cost, largely eliminates the cost difference between alternatives 3, 4A, 4B, 5A, 5B, and 5C, given the uncertainty in actual cost. The economies of scale are offset by reduced capital costs. Before drawing conclusions based on the Lower Cost Range results, the reader should recognize that selection of an approach using existing facilities with expensive upgrades, (over and above correction of known vulnerabilities¹) significantly changes the cost comparisons. In this situation, cost would tend to increase toward the Upper Cost Range.

Based on this cost evaluation, it is not possible to determine whether Direct Disposal or Processing is the least expensive ultimate disposition strategy. It is likely that this determination is fuel-specific. The uncertainty regarding repository waste acceptance criteria, processing technology selection, applicability of RCRA, etc., overwhelm any apparent differences.

An early repository opening resulting in shutdown of some SNF management sites could significantly lower total Department costs on a constant year dollar basis.

¹DOE recently assessed its SNF storage facilities for vulnerabilities (conditions that pose current or future safety problems requiring action). The Action Plan (Reference 3) proposes near-term corrections of these vulnerabilities. Long-term actions may also be required at a later point in time.

7. UNCERTAINTY

A number of variables contribute to uncertainties in the estimates presented herein. The primary factors are discussed below. While this section explores the uncertainties in the bottom line costs, it must be stressed that this cost evaluation does not support budgetary efforts. This cost evaluation is intended only to assist DOE in its decisions regarding how to proceed with interim management of SNF. As discussed in Section 8, *Sensitivity*, the relative ranking of alternatives is not generally affected by these uncertainties.

Typical project uncertainty — A recent study found that DOE Environmental Management project growth (variation from project funding to actual costs) has historically averaged 48% with a standard deviation range of -23% to +118% (Reference 11). This historic uncertainty in actual costs is applicable to estimates for SNF management. The uncertainty would apply even if a disposition strategy were selected, site-specific implementation decided, and designs developed.

Absence of detailed designs — The estimates presented here are largely based on representative facility designs, rather than detailed designs for specific applications. It is expected that use of similar rather than project-specific designs may result in uncertainties similar in size to the typical project uncertainties discussed above.

Uncertainty in disposition — The eventual strategy(ies) to be utilized for disposition of DOE SNF is not currently known and may not be decided for years. This cost evaluation considers two of the many disposition strategies possible. Furthermore, it is unlikely that all SNF will follow the same disposition strategy, as is assumed here.

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8. SENSITIVITY

The results of the cost estimate are dependent on the assumptions and bases used; therefore, it is important to understand how the results are affected if the assumptions change. Differences in total costs and cash flows may be significantly affected by a change in the assumptions, while the relative cost-effectiveness of the alternatives may not be affected. Since this report is focused on supporting a decision on where to manage SNF, absolute differences may not affect the conclusions as long as the relative ranking of alternatives is not affected.

Table 8-1 summarizes the variables considered in this sensitivity assessment. As shown, most of the variables do not affect the relative cost ranking of alternatives even though they may affect the total costs. The following sections provide additional insight into the sensitivity of the results to these variables.

8.1 Scaling Exponents

Scaling exponents are used to adjust new facility costs for variations in capacity, as explained in Section 5.4 and Appendix C. The scaling exponents determine the significance of "economies of scale" and therefore have the potential to affect the relative ranking of alternatives.

Constant Year Dollar Basis — To determine if variations in the scaling exponent would affect the relative ranking, costs were calculated for a broad range of scaling exponents (i.e., from 0.2 to 0.5). Figure 8-1 displays how significantly the scaling exponent affects the relative ranking of alternatives for the Upper Cost Range of Storage Only. In the graph, the best estimate scaling exponent is shown as a bold line, and the variations are shown as thin lines.

NPV Basis — The effects of varying the scaling exponent are the same on an NPV basis as they are on a constant-year dollar basis.

Cash Flow Basis — The cash flow is affected by variations in the scaling exponent in the same manner that the constant-year dollar results are affected. If a cash flow limit were known, some additional alternatives might exceed or fall below the limit as a result of the changes in overall costs.

8.2 Timing of Actions

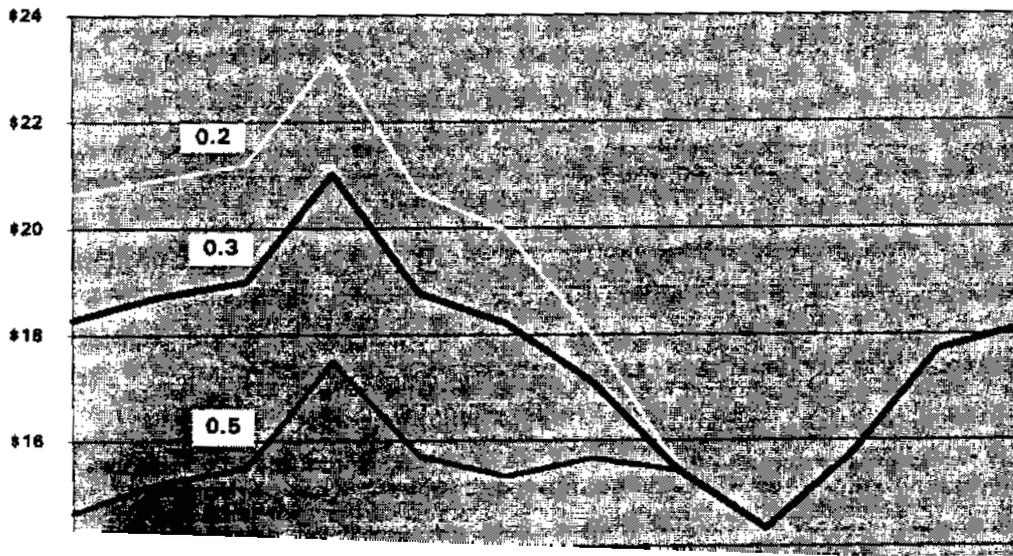
A repository for DOE SNF is currently not expected to be available until after 2015. The life-cycle cost evaluations performed were based on having all DOE SNF and high-level waste inventory ready for the repository on or before 2035. The actual shipment date for most of the SNF may be earlier or later than the 2035 date. Accelerating this schedule would reduce the amount of SNF in storage.

Table 8-1. Summary of the Sensitivity Study.

Section	Variable	Affects Ranking of Alternatives?	Comments
8.1	Scaling Exponents	Yes	Scaling exponents above 0.3 reduce the economies of scale and improve the relative rank of Alternatives 1 through 4B. Scaling exponents less than 0.3 improve the relative rank of Alternatives 5A through 5E.
8.2	Timing of Actions	No	Accelerating disposal schedules is of minimal benefit unless a significant number of facilities can be shut down. This is not the case for most alternatives due to assumed continued receipt of Navy, foreign research reactor, and domestic research reactor fuel. Schedule delays increase costs roughly \$300M per year of delay due to infrastructure and O&M.
8.3	Repository WAC	No	Changes in the repository WAC can dramatically affect the comparison of management strategies, but not the ranking of alternatives within a strategy. Changes in this assumption merely increase/decrease the costs for all alternatives by a fixed amount and do not affect their relative ranking.
8.4	RCRA	No	RCRA treatment increases the costs for all alternatives. Since INEL already has over 90% of DOE fuel types and none of the alternatives disperse these fuels, the added cost is the same for all alternatives. The Upper and Lower Cost Ranges already consider RCRA treatment and no RCRA treatment, respectively.
8.5	Continued Use of Existing Facilities	Yes	The extent to which existing facilities are used significantly affects relative ranking. Upper and Lower Cost Ranges already portray the maximum and minimum use of existing facilities.

Table 8-1. Summary of the Sensitivity Study (continued)

Section	Variable	Affects Ranking of Alternatives?	Comments
8.6	D&D of Excess Facilities	No	Increased competition for funds could stretch schedules and increase costs. See Section 8.2.
8.7	Transportation Costs	No	Increasing or decreasing transportation costs by a factor of 2 increases or decreases total costs by about 2%.
8.8	Alternative Process Technologies	Unlikely	Could significantly affect comparison of management strategies, but is unlikely to affect relative rank of alternatives unless costs are dramatically reduced.
8.9	O&M Costs	Potentially	As O&M costs increase, the advantage of SNF consolidation also increases. Conversely, as O&M costs decrease, the advantage of consolidation decreases.



However, to reduce costs in the out years, it is essential that facilities be closed, which would require that all SNF be removed from these facilities. Accelerating SNF shipments to the repository without closing facilities would result in little cost savings.

Constant-Year Basis - If the SNF/high-level waste shipments actually begin by 2015, then the amount of SNF in storage could be significantly reduced in the early years relative to the basis used in the evaluation. However, the number of facilities operated is not significantly affected by early disposition. Most facilities cannot be shut down early because of the assumed continual inflow of SNF from Navy, domestic test and research, and foreign sources. On a constant-year dollar basis, there is little difference because storage facility O&M costs are not highly dependent on the amount of SNF in storage, and any SNF preparation activities merely are being transferred in time.

If the SNF/high-level waste is not prepared for disposal until after 2035, then the storage costs will increase significantly, because facilities that could otherwise be shut down must continue to operate. The total costs will increase by 1% to 2% per year delayed.

NPV Basis - On an NPV basis, accelerating the start of disposition activities to 2015 will increase costs. This occurs because the costs associated with disposition are being brought forward in time, therefore reducing the degree of discounting. Delay of all activities whenever possible will decrease the costs on an NPV basis.

Cash Flow Basis - The cash flow may or may not be affected by accelerating the disposition schedule, depending on the extent to which the schedule is compressed or stretched. It is not possible to draw conclusions from a cash flow perspective without specifying the schedule.

8.3 Repository WAC

The repository WAC and certification requirements are not yet established for DOE SNF. This fact introduces uncertainties into all ultimate disposition life-cycle cost evaluations. This is particularly true for SNF that is dramatically different than commercial SNF, for example, high-enrichment SNF. This evaluation was based on a single assumption for MPC loading (i.e., a volumetric constraint), which may be optimistic for high-enrichment SNF due to the high fissile mass loadings. The eventual repository WAC could even preclude disposal of high-enriched SNF. This sensitivity study explores the significance of repository WAC on ultimate disposition costs and relative ranking of alternatives.

Constant-Year Dollars - Changes in the repository WAC will dramatically affect the comparison of SNF management strategies, but they do not affect the relative ranking of alternatives within a strategy. Figure 8-2 displays the total repository expenses for DOE SNF as a function of the high-enriched uranium fissile loading per canister under Direct Disposal.

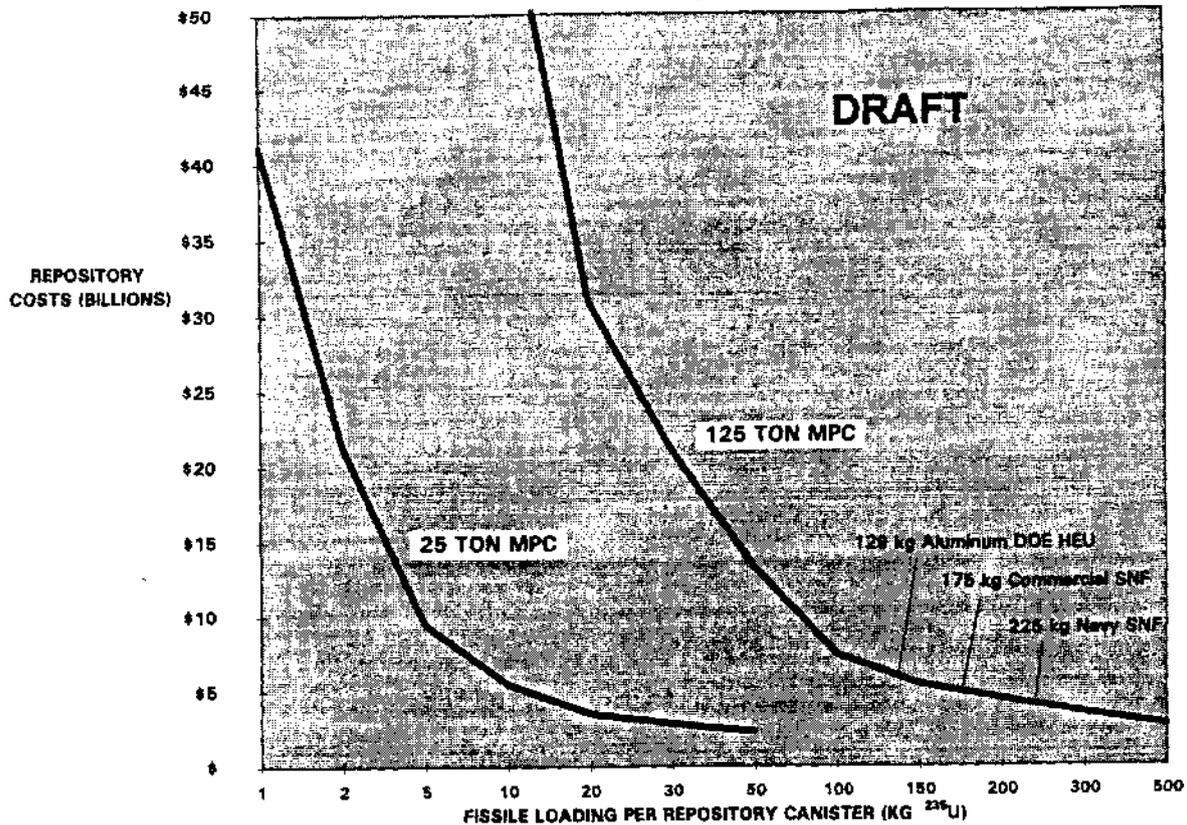


Figure 8-2. Effects of fissile loading on repository canister costs.

Severe fissile loading constraints will result in MPCs that are only partially full volumetrically. In this case, it is more cost-effective to use smaller, less expensive MPCs. Figure 8-2 presents costs for both a 125-ton MPC currently being considered for use with commercial SNF and a small 25-ton MPC previously considered. The volumetric limit of the 25-ton MPC is not known, but it is expected to be less than 50 kg of ²³⁵U.

NPV - The repository WAC affect the NPV costs in the same way that they affect the constant-year dollar costs. However, since the repository expenses are near the end of the life cycle, the effect is reduced relative to the constant year dollar case.

Cash Flow - Since repository expenses are concentrated in the final phase of the life cycle, changes in the repository WAC have an accentuated impact on the cash flow in these later years. The cash flow for Storage Only is not affected by the repository WAC. The Processing strategy is only marginally affected, since high-level waste forms are expected to meet the repository WAC.

8.4 RCRA

DOE SNF is not currently subject to RCRA regulations because SNF has not been declared a waste. If DOE SNF is eventually declared a waste, and assuming it will not be exempted from the requirements of RCRA, then preliminary studies indicate that there are some fuel types (less than 5%) that exhibit RCRA characteristics. These fuels are primarily those that have metallic sodium bonds between the fuel matrix and the cladding, and may include those that have a uranium-carbide fuel matrix. The Upper Cost Range has been based on the assumption that RCRA characteristics must be removed by treatment and the Lower Cost Range is based on RCRA not applying to SNF. RCRA treatment costs are estimated at \$1.6B.

Constant-Year Dollars - RCRA treatment increases the costs associated with all alternatives. Over 90% of the DOE SNF that may require RCRA treatment is already at the INEL (excludes the Fort St. Vrain fuel not in DOE possession). None of the alternatives disperse this fuel to multiple sites, so centralized RCRA treatment occurs in all alternatives. Therefore, RCRA treatment costs are a constant adder to all alternatives. Since all fuel is being processed under the Processing strategy, RCRA requirements will have no effect for that strategy.

A requirement for RCRA treatment could affect the timing of actions, either accelerating or delaying actions. Section 8.2 provides a discussion on the overall effects of timing.

NPV - The effect on NPV of RCRA treatment requirements is greater than the constant-year dollar analysis since RCRA is likely to be an up-front cost and, therefore, subject to less discounting.

Cash Flow - RCRA treatment increases the up-front expenditures for Direct Disposal.

8.5 Continued Use of Existing Facilities

A primary difference between sites (and between alternatives to some extent) is the presence and potential for use of existing facilities. The cost evaluation addresses maximal use of existing facilities with minimal upgrade under the Lower Cost Range and minimal use of existing facilities under the Upper Cost Range. The majority of existing SNF management facilities are not in full compliance with modern design standards. The cost of upgrading these facilities to meet current DOE Order requirements could equal or exceed the cost of replacing these facilities. This cost evaluation has not attempted to estimate the upgrade costs, but has bounded these costs with the Upper Cost Range where new facilities are built. Any attempt to estimate the actual costs would be highly speculative, because it would involve anticipating the degree of compliance and facility upgrades that would be accepted.

8.6 D&D of Excess Facilities

This section provides an estimate of the funding required for surveillance and maintenance of excess facilities plus eventual D&D costs. These costs will likely be competing for DOE funding and could influence decisions on whether or not to utilize existing facilities. It may also impact funding availability, which could affect the selection of alternatives.

Constant-Year Dollars - The D&D cost for existing SNF facilities (including old reprocessing facilities) could be \$8 billion. These costs are a significant fraction of the SNF management costs and could result in budget constraints, which may limit the viability of some alternatives.

NPV - The effect of decommissioning cost and timing on NPV is less than for the constant year dollar analysis since decommissioning is a back-end cost subject to greater discounting.

Cash Flow - The schedule of D&D activities is highly speculative, but most of these actions would not be expected until the mid or later phases of the 40-year SNF period. Depending on how quickly these facilities are decontaminated and decommissioned, the annual budget requirements could approach a half billion dollars per year. If the D&D activities are concentrated in the later years, then initial construction activities should not be significantly affected. The out-year activities, such as disposition, could be delayed as a result of funding competition. The impact of delays in disposition are addressed in Section 8.2

8.7 Transportation Costs

The transportation analysis for the *SNF & INEL EIS*, as well as for this cost evaluation, was based on historic data rather than projecting the casks and transportation system that might actually be used. As a result, the eventual transportation requirements could differ somewhat from the basis used here. In addition, it is possible that future requirements (such as emergency response equipment and training for states) may result in higher than anticipated costs.

Constant-Year Dollars - Increasing or decreasing the transportation costs by a factor of 2 results in less than 2% variation in the life-cycle costs for the Storage Only strategy and smaller impacts on the Direct Disposal and Processing strategies.

NPV - Since transportation occurs early in the life cycle, a factor of 2 increase or decrease in transportation costs will have a slightly greater impact on the NPV costs. While somewhat more significant than on a constant-year dollar basis, the impact on the NPV costs is still less than 2%.

Cash Flow - The affect on cash flow from a factor of 2 increase and decrease in transportation costs for Storage Only is small. The influence that variations in transportation cost have on the Direct Disposal and Processing strategies is even smaller, since the total life-cycle costs are greater for those strategies.

8.8 Alternative Process Technologies

This evaluation considers only the aqueous technologies for the Processing strategy. As part of the ultimate disposition decisions, it will be important to consider whether it is desirable or necessary to process DOE SNF (e.g., for cost savings or for required immobilization). There are numerous candidate processing technologies to be considered and selection of technologies may be on a fuel-specific basis. It is likely that some of these alternative technologies will be more cost effective than aqueous processing for some or all fuels. Since support for ultimate disposition decisions is outside the scope of this evaluation, no attempt was made to optimize the technology selection. Therefore, it is inappropriate to attempt to compare the cost between management strategies.

The alternative technologies include processes that do not separate the fissile materials (e.g., melting, oxidation, and mechanical shredding) and processes that do include separation of fissile materials (e.g., molten salt electro-refining and halide volatility). Volume I, Appendix J of the *SNF & INEL EIS* provides an overview of some of these alternative technologies.

If alternative technologies are eventually used, it is reasonable to assume that they would be comparable to, or more cost effective than, aqueous processing. If the facility costs are comparable, then the results presented here apply. If facility costs for alternative technologies are much lower, there will be less of a penalty for not consolidating processing.

8.9 O&M

O&M costs include direct management activities and other indirect infrastructure costs. The indirect infrastructure costs are difficult to quantify as they extend across a broad range of support organizations that do not directly contribute to SNF management activities, e.g., fire protection or security. Frequently these indirect support functions are shared with other programs and the allocation to SNF management becomes a matter of perspective.

Since O&M dominates the total costs for all scenarios, uncertainty in the O&M cost estimates will greatly affect the total cost and may significantly affect the relative ranking of alternatives. As O&M costs increase, the advantage of SNF consolidation also increases. Conversely, as O&M costs decrease, the advantage of consolidation decreases, and the potential to use existing facilities becomes more significant.

9. REFERENCES

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APPENDIX A

GENERIC FACILITY DESCRIPTION

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APPENDIX A: GENERIC FACILITY DESCRIPTION

The generic facility model consists of facilities required for Storage Only, Direct Disposal, or Processing the entire (DOE) SNF inventory. The major activities performed by the generic facilities for each management strategy are shown in Table A-1. An assumed schedule for construction and operation of these activities is shown in Figures A-1, A-2, and A-3. These schedules are for a scenario that encompasses centralization with full capacity; i.e., a single facility that manages the entire DOE SNF inventory. The total project costs (TPC) associated with these facilities (Reference A-1) are summarized in Table A-2.

Table A-1. Generic Facilities Potentially Required for Each Management Strategy.

Storage Only	Direct Disposal	Processing
Characterization & Canning Dry Storage Pool Storage Naval Fuel Examination Technology Development	Characterization & Canning Dry Storage Pool Storage Naval Fuel Examination Technology Development Na-Bonded RCRA Treatment Graphite (carbide) RCRA Treatment	Dry Storage Pool Storage Low-Enriched Uranium Headend Fluorinel Headend Graphite Headend Electrolytic Headend Special Fuels Headend Uranium Blending and Separation High-Level Waste Immobilization Naval Fuel Examination Technology Development

Generic facilities are used in this evaluation when a site does not currently have certain capabilities or sufficient capacity to manage the SNF associated with the alternative being evaluated. The generic facilities are either added directly or scaled, depending on the capacity required for each alternative. Capacity requirements are provided in Table D-1 (see Appendix D). The generic facilities are described below.

Characterization and Canning Facility

The function of the characterization and canning facility is to characterize the physical and radiological properties of the fuel and to can the SNF as necessary to assure containment of fission products during interim storage or for final disposition. The facility is designed to characterize and can fuel (intact, scrap, and rubble) of various sizes, shapes, and concentrations of uranium enrichment. The facility also conditions the SNF by removing fuel from degraded canisters, dismantling and removing the non-fuel hardware, and cutting the fuel into appropriate lengths as needed for packaging into new canisters that are compatible with the repository disposal method.

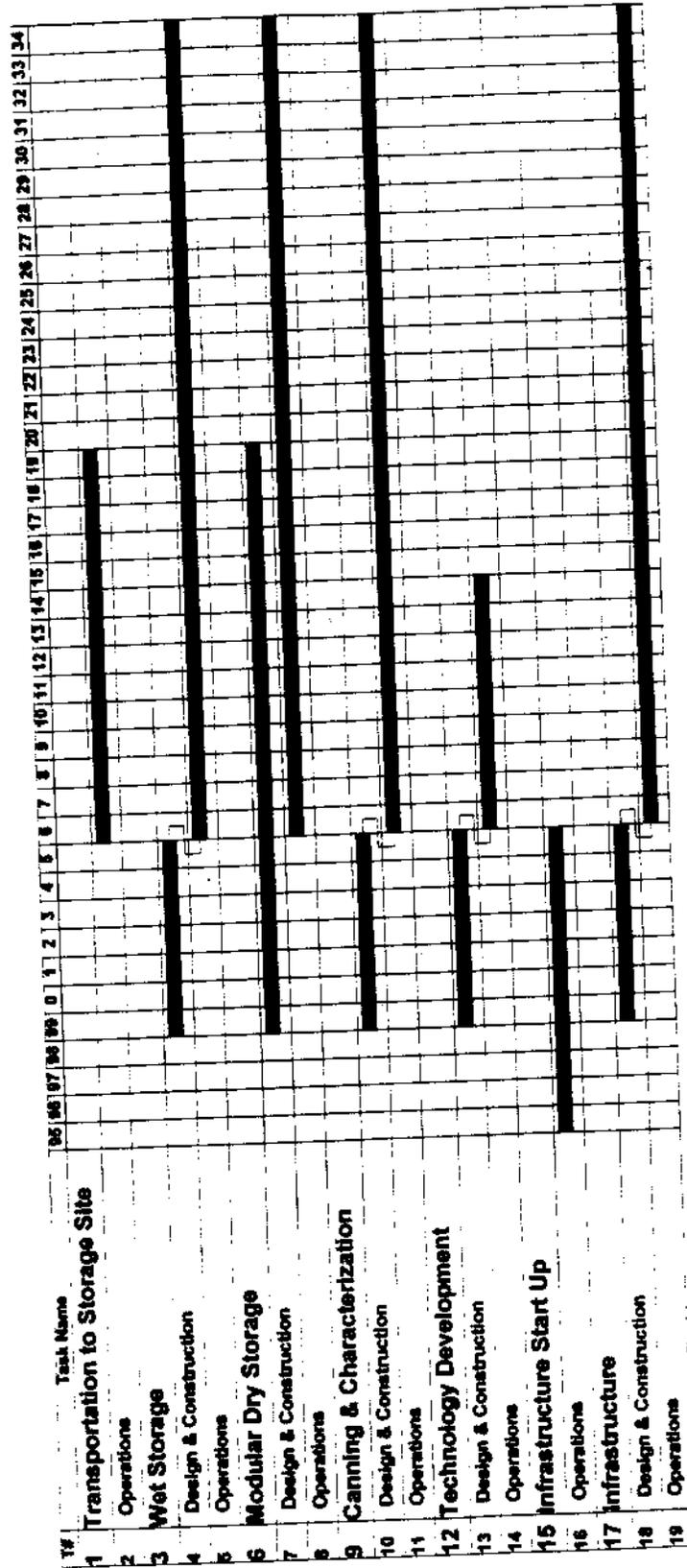


Figure A-1. Schedule for Storage Only functions.

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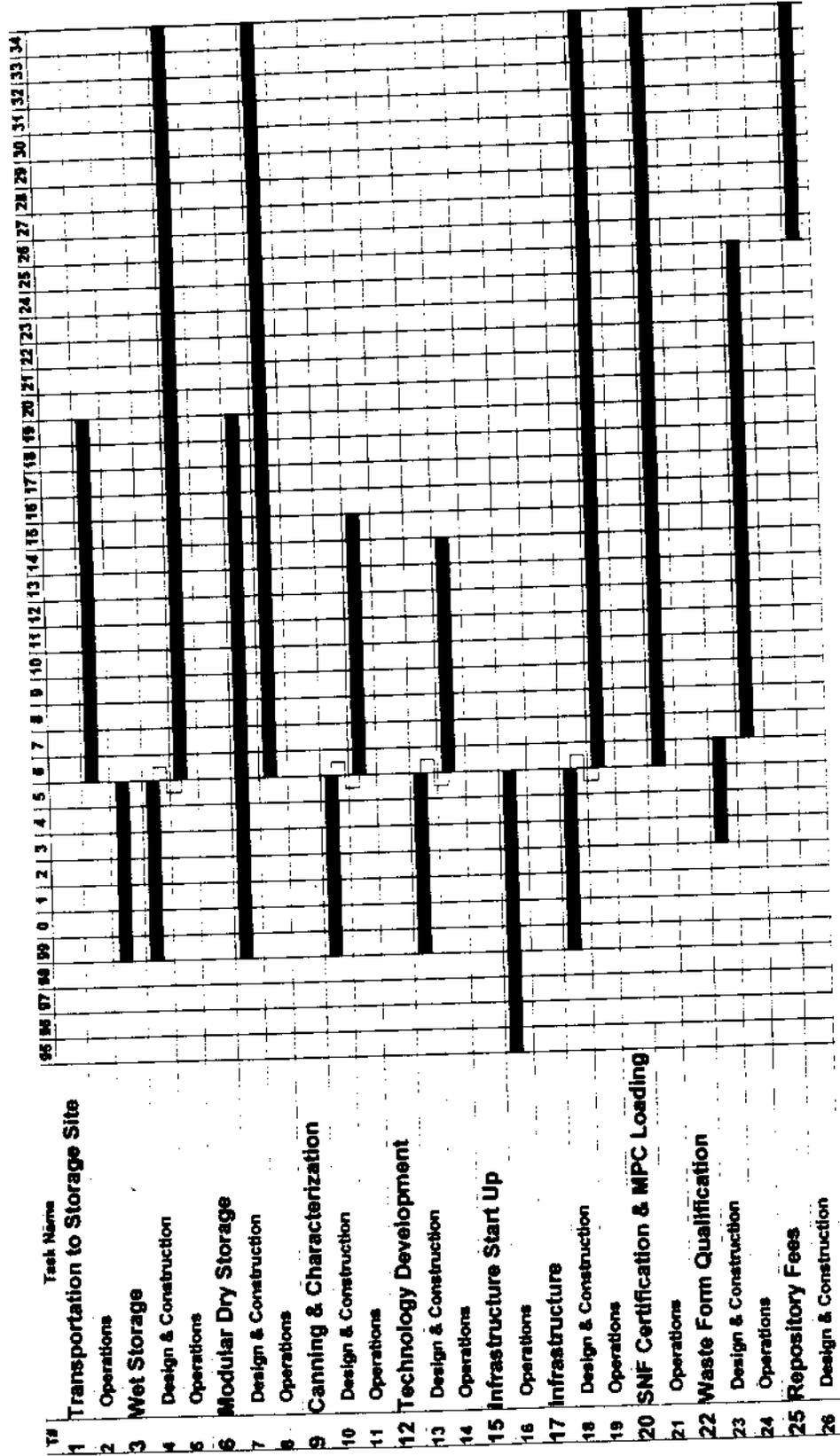


Figure A-2 . Schedule for Direct Disposal functions.

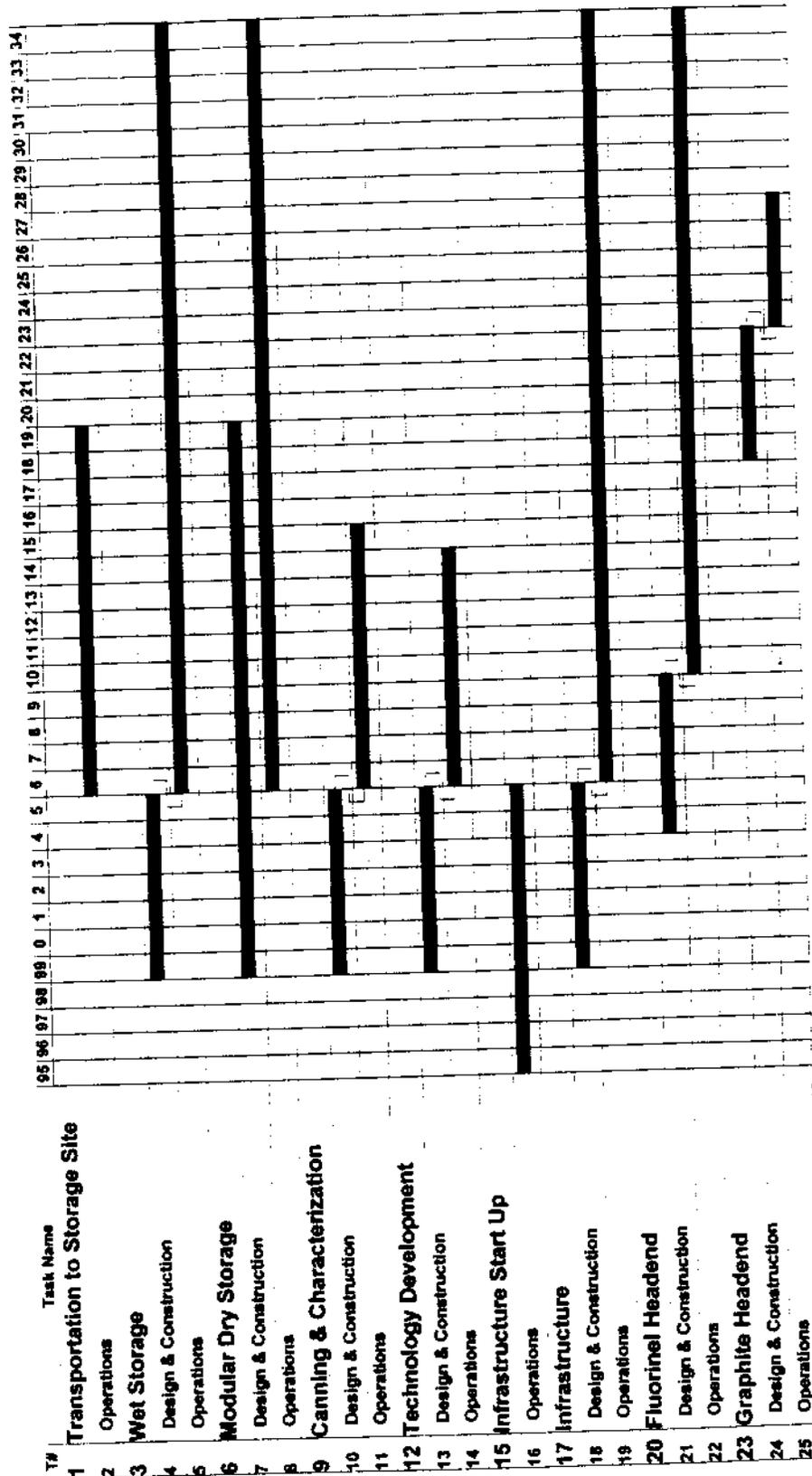


Figure A-3. Schedule for Processing functions.

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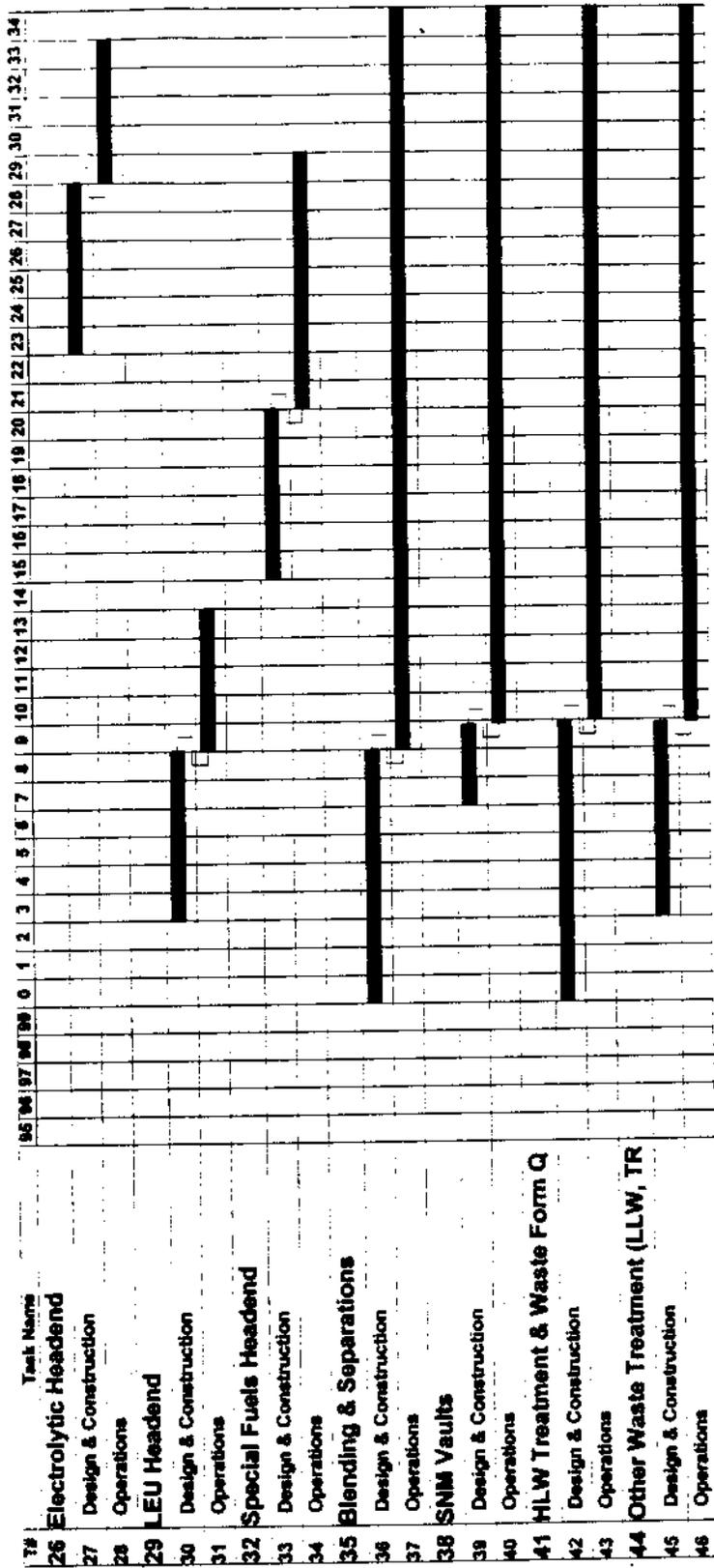


Figure A-3 (Continued). Schedule for Processing functions.

Table A-2. Cost Summary for Generic Facilities

Generic Facility (MTHM)	Capital Cost (Millions of 1995 Dollars)	Annual O&M Cost (Millions of 1995 Dollars)
Characterization & Canning (2760 MTHM total)	403	31
Dry Storage (2760 MTHM)	524	7
Pool Storage (1800 storage positions)	173	10.6
Low Enriched Uranium Headend (720 MTHM/yr)	600	29
Fluorinel Headend (140 MT total mass/yr)	479	29
Graphite Headend (1.3 MTU/yr)	609	34
Electrolytic Headend (17 MTHM/yr)	548	31
Special Fuels Headend (17 MTHM/yr)	358	22
Uranium Blending & Separation (575 MTHM/yr)	1,200	56
High Level Waste Immobilization (200 MTHM/yr)	1,270	66
Naval Fuel Examination (55 MTHM/over 40 yrs)	800	59
Technology Development (all DOE SNF types)	134	18
Infrastructure (2760 MTHM)	1465	93
Graphite (carbide)RCRA Treatment (1.3 MTHM/yr)	609	34
Na-Bonded RCRA Treatment (ANL-W Fuel Cycle Facility) (18 MTHM/yr)	9	39

Dry Storage Facility

The SNF dry storage facility is used for storage of containerized SNF. The facility consists of a large storage yard holding individual SNF canisters in either vertical or horizontal concrete vaults (bunkers), concrete casks, or in metal casks. The facility uses a passive ventilation system to remove heat generated by the stored SNF. The vault or cask shell provides a path for cooling air to flow over the SNF canister. Several such facilities are offered as a predesigned packaged system by United States and European vendors. These designed packaged systems are based on commercial power reactor SNF. However, it is expected that system performance evaluations will show their adequacy for DOE SNF. The construction phase overlaps operations for the dry-storage phase; the modular nature of the facility units allow additional modules to be built as needed.

Pool Storage Facility

The pool storage facility is used for storage of canned or uncanned SNF. Spent nuclear fuel recently discharged from the reactor utilizes pool storage until decay heat declines to levels that permit passive dry storage. The facility consists of a bay for loading and unloading transportation vehicles and several fuel pools and cubicles that house the associated support systems. The pools hold individual SNF canisters and assemblies in

vertical fuel racks. The facility uses active components for cooling and cleaning the pools. Ventilation is provided in the space above the pool.

Low-Enriched Uranium Headend Processing Facility

A new low-enriched uranium headend processing facility provides a headend facility that could process low enriched zirconium-clad fuel, principally N-Reactor fuel. The facility would mechanically shear fuel elements, exposing the fuel for dissolution by nitric acid. The resulting nitric acid solution, containing the uranium and the waste products, would be transferred to the uranium-separation process. The zirconium cladding hulls, left after fuel dissolution, would be decontaminated, compacted, and disposed as waste.

Blending and Separation Facility

The uranium separation facility blends uranium solutions resulting from headend processing down to low enrichments and separates the uranium from the waste (actinides and fission products). The separation process consists of three cycles of solvent extraction using aqueous (nitric acid) and organic (tributyl phosphate in a kerosene type solvent) solutions. The first cycle extraction separates uranium from fission products, and the subsequent extraction cycles separate the transuranics, including plutonium, from the uranium. The organic solvents are recovered and reused. The uranium is further processed into solid oxide forms. This separated uranium is not a proliferation risk because of its low enrichment. The aqueous high level waste stream, containing fission products and other wastes, is transferred to the high-level waste treatment facility for immobilization.

Fluorinel Headend Facility

High-enriched zirconium-clad nuclear fuels, including the naval fuels, are processed using the Fluorinel dissolution process. This process consists of using soluble neutron-absorbing hydrofluoric acid to dissolve the zirconium and uranium in a batch process.

An aluminum nitrate solution complexes the unused fluoride ions with aluminum to reduce the solution's corrosiveness. Water is used to dilute and stabilize the solution for stability to prevent precipitation, and nitric acid provides additional nitrate ions and pH adjustment to enhance uranium separation in the following extraction process. Following dissolution and complexing, the product solution is collected in accountability vessels where the uranium mass is accurately measured, and the solution is transferred to a uranium blending and separations facility.

Graphite Headend Facility

Graphite SNF is received into a hot cell in shipping casks, which will be opened and the fuel elements unloaded. The fuel is transferred to a fuel disassembly area by cranes and a shuttle car. In the disassembly hot cell, any metal parts are removed and the fuel prepared for incineration. The graphite blocks are crushed in a shredder and size screened for burning in a fluidized-bed primary burner. From the primary burner, combustion gases and ash are separated by cyclone-type separators, and the ash (fuel particles) placed in temporary storage as necessary before being crushed and fed into a secondary burner. Both the primary and secondary burners have provisions for storing fluidized bed materials, and the primary burner has provisions for segregating and recycling unburned solids from the bed material. The second burning operation is required to eliminate significant quantities of organic compounds that might be deleterious to subsequent solvent extraction operations. From the secondary burner, combustion gases and ash will be separated and the ash will be placed into interim storage as necessary before further processing. Combustion gases will be treated to remove the semi-volatile fission products and iodine, and will be passed through remote-serviced high efficiency particulate air (HEPA) filters before being released to the off-gas system.

Electrolytic Headend Facility

Stainless steel and aluminum-clad fuels are dissolved in an electrolytic dissolver using nitric acid. A large rectifier will convert AC electrical power to DC power, supplying several thousand amps in the 5-20 volt range. The dissolver product is pumped through a clarification system and collected for subsequent solvent extraction operations in the blending and separation facilities. Undissolved solids will be periodically back flushed from the filter to form a slurry and collected for further processing, as appropriate.

Special Fuels Headend Facility

The special fuels headend facility is required for the processing of many special fuel types that cannot be processed through any of the other headend facilities. In general, the quantities of each special fuel type are small. Individual custom scale headend modules will be constructed. A sufficient buffer zone will be provided around the custom equipment for remote maintenance and operation. After conversion to liquid form, the resultant solutions are transferred to the blending and separation facilities

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High-Level Waste Immobilization Facility

The high-level waste immobilization facility provides the processes necessary to immobilize the high-level waste produced in the blending and separation facility. The facility uses a separation process and a vitrification process. Such processes produce a relatively small stream of high-level waste form, vitrified into glass or glass ceramic, suitable for placement in a geologic repository, and a large quantity of low-level waste form contained in drums or canisters suitable for transport and disposal in an appropriate waste site.

Naval Fuel Examination Facility

Naval SNF is examined to support Naval Nuclear Propulsion Program needs (for example, continued safety and core life extension). These examination activities would occur at a facility similar to the Expanded Core Facility located at the Idaho National Engineering Laboratory. The Expanded Core Facility is a water basin with adjoining remotely operated hot cells. All SNF at the Expanded Core Facility is visually examined externally for evidence of any unusual condition such as unexpected corrosion, unexpected wear, or structural defects. After the fuel assembly structural components have been removed, the interior of the assembly is examined for the conditions discussed above. In addition, the assembly is examined for distortions (from irradiation, heat, or the fission process) that could interfere with the even distribution of primary coolant and consequent heat removal. The inspection also checks for possible flow obstructions due to foreign material or excessive corrosion product buildup. Selected cores are given more detailed examinations for such purposes as confirming the adequacy of new design features, exploring materials performance concerns, and obtaining detailed information to confirm or adjust computer predictions of neutron physics, heat transfer, or hydraulic flow and distortion. These detailed examinations may include metallography to determine corrosion film thicknesses, dimensional measurements to determine fuel assembly distortion, and radiochemical analysis to determine core depletions, as well as other inspections.

RCRA Treatment of Graphite (Carbide)

Treatment of graphite based SNF involves a process similar to Graphite Headend. The same two-stage crushing and burning equipment are utilized (see description of the Graphite Headend). However, rather than dissolving the uranium, this facility would encapsulate it (similar to grouting). Depending upon the repository waste acceptance criteria, neutron absorbers or depleted/natural uranium may need to be added for criticality prevention. The resulting encapsulated material is ready for packaging and disposal.

RCRA Treatment of Sodium (Na)-Bonded SNF

The SNF that utilizes metallic sodium to conduct heat from the fuel matrix to the cladding may require RCRA treatment to remove the sodium. The molten-salt electro-refining process at ANL-W could be used for this purpose since nearly all of the Na-bonded fuel is at ANL-W. This process has three outputs: 1) pure uranium (which can be blended with low-enriched uranium either for use in commercial power reactors) or depleted uranium for disposal, 2) concentrated fission products in a stable, disposable, high-level mineral waste form, and 3) residual uranium and transuranic elements in a durable metallic form. Capital costs are based on treatment at ANL-W since treatment is not considered at any other site.

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APPENDIX B

USE OF EXISTING FACILITIES

APPENDIX B: USE OF EXISTING FACILITIES

For each alternative and management strategy, assumptions were made regarding the use of existing facilities at the candidate sites. In general, existing facilities were assumed to be utilized under the Lower Cost Range, whereas new facilities were constructed for the Upper Cost Range. No attempt was made to determine the useful life of these existing facilities since the cost evaluation is only interested in presenting Lower and Upper Cost Ranges. If existing facilities either are currently compliant with or receive a waiver from applicable codes and standards (Reference B-1), then the Lower Cost Range would reflect the expected costs. Replacement of non-compliant facilities with new compliant facilities represents the Upper Cost Range. Some of the non-compliant facilities could be brought into compliance through upgrades. These upgrades are expected to place costs somewhere between the Upper and Lower Cost Ranges. However, no attempt was made to examine this case since this variation is bound by the Upper and Lower Cost Ranges.

All DOE sites with SNF storage facilities have been previously examined for vulnerabilities (Reference B-1). This reference provides a high-level overview of compliance with existing design standards and current physical status of these facilities. If the DOE was to consider using existing facilities during the next 40 year period, a substantial design life extension program could be appropriate.

Tables B-1 through B-3 identify site-specific existing facilities that are being considered for use under each cost range for the various alternatives/management strategies. If no functional entry is shown, it can be assumed that new facilities will be built for purposes of the cost evaluation as needed. The Hanford Site, Idaho National Engineering Laboratory, and Savannah River Site are the only locations considered that have existing facilities that are feasible to use. The Oak Ridge Reservation and the Nevada Test Site were assumed to require new facilities under both cost ranges. Appropriate credits were applied to the Oak Ridge Reservation to reflect its existing infrastructure.

References

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**Table B-1. Existing Hanford Site Spent Nuclear Fuel Management Facilities
Currently Being Considered For Use.**

Function	Facility	No Action		All Other Alternatives	
		Lower Cost Range ¹	Upper Cost Range ²	Lower Cost Range	Upper Cost Range
Storage	105 KE	Replaced	Replaced	Replaced	Replaced
	105 KW	Replaced	Replaced	Replaced	Replaced
	200 Area	Utilized	Utilized	- ³	-
	Bldgs. 324, 325, 327	-	-	-	-
	PUREX	-	-	-	-
	Fast Flux Test Facility	Utilized	Utilized	-	-
	T-Plant	Utilized	Utilized	-	-
Stabilization	Fuel and Material Examination Facility ⁴	N.A. ⁵	N.A.	Utilized	-
Infrastructure	Existing Utilities and Support	Utilized	Utilized	Utilized	Utilized

Footnotes for Table B-1:

1. Maintenance-type improvements will be included.
2. Extensive improvements will be implemented.
3. The dash indicates the facility will not be utilized long-term for those scenarios.
4. This building shell would require new equipment.
5. Not applicable.

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Table B-2. Existing Idaho National Engineering Laboratory Spent Nuclear Fuel Management Facilities Currently Being Considered For Use.

Function	Facility	No Action		All Other Alternatives	
		Lower Cost Range ¹	Upper Cost Range ²	Lower Cost Range	Upper Cost Range
Storage	Irradiated Fuel Storage Facility (dry storage)	Utilized	Utilized	Utilized	Replaced
	CPP-749 Peachbottom Fuel Storage Facility	Utilized	Utilized	Utilized	Replaced
	CPP-666 Fluorinel & Storage Facility	Utilized	Utilized	Utilized	Utilized
	Test Area North, Test Reactor Area, and Power Burst Facility	- ³	-	-	-
	Hot Fuel Examination Facility	Utilized	Utilized	Utilized	Replaced
	Radioactive Scrap & Waste Facility	Utilized	Utilized	Utilized	Replaced
Naval Fuel Exam	Expended Core Facility	N.A. ⁴	N.A.	Utilized ^{4,5}	Utilized ^{4,5}
Canning & Characterization	Hot Fuel Examination Facility	Utilized	Utilized	Utilized	Utilized
	CPP-666 Fluorinel & Storage Facility ⁶	-	-	Utilized	Utilized ⁷
Shipping & Receiving	CPP-666 Fluorinel & Storage Facility	Utilized	Utilized	Utilized	Utilized
Blending and Uranium Separation	CPP-697 Fuel Processing Facility	N.A.	N.A.	Utilized	Utilized
Fluorinel Headend	CPP-666 Fluorinel & Storage Facility	N.A.	N.A.	Utilized	Utilized
Infrastructure	Existing Utilities and Support	Utilized	Utilized	Utilized	Utilized

Table B-2 Footnotes:

1. Maintenance-type improvements will be included.
2. Extensive improvements will be implemented.
3. The dash indicates the facility will not be utilized long-term for those scenarios.
4. ECF is closed under the No Action and Decentralization 2A & 2B alternatives.
5. Upgraded as necessary, including dry cell facility.
6. This facility would require new equipment.
7. Except for Centralization at the INEL, under which a new facility would be built.

Table B-3. Existing Savannah River Site Spent Nuclear Fuel Management Facilities Currently Being Considered For Use.

Function	Facility	No Action		All Other Alternatives	
		Lower Cost Range ¹	Upper Cost Range ²	Lower Cost Range	Upper Cost Range
Storage	Reactor Disassembly Basin	Utilized	Utilized	Utilized	Replaced
	Receiving Basin for Offsite Fuels	Utilized	Utilized	Utilized	Replaced
Shipping & Receiving	Receiving Basin for Offsite Fuels	Utilized	Utilized	Utilized	Replaced
Low-Enriched Uranium Separation	F-Canyon ³	N.A. ⁴	N.A.	Utilized	Replaced
High-Enriched Uranium Separation	H-Canyon ³	N.A.	N.A.	Utilized	Replaced
High Level Waste	Defense Waste Processing Facility ⁵	N.A.	N.A.	Utilized	Utilized
Infrastructure	Existing Utilities and Support	Utilized	Utilized	Utilized	Utilized

Table B-3 Footnotes:

1. Maintenance-type improvements will be included.
2. Extensive improvements will be implemented.
3. This facility also has the capability of dissolving some aluminum fuels.
4. Not applicable.
5. This facility is under construction and is assumed to be available for use under both the lower and upper cost ranges as needed.

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APPENDIX C

NEW FACILITY COST SCALING

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APPENDIX C: NEW FACILITY COST SCALING

Introduction

The SNF management alternatives result in varying capacity requirements for new facilities and, therefore, in varying costs. To develop planning cost estimates for the many facilities with differing capacities, a common industry approach called "Scaling" was applied. This scaling approach allows for the development of planning cost estimates for numerous facilities with different capacities using a known facility as a basis.

Facility capital and O&M costs are clearly not directly proportional to capacity in most cases. For example, it is not possible to build two 1,000 ft² houses for the same cost as one 2,000 ft² house of comparable quality. The costs savings for the single larger house are due to factors like the surface-to-volume ratios, replication of utilities, etc.. These savings for larger capacities is commonly referred to as the "economy of scale" and is prevalent in many facets of business.

The scaling method used for this cost evaluation greatly affects the results. If there was no economy of scale, then there would be no difference among the alternatives except for the potential use of existing facilities. The method used for scaling costs determines the calculated cost penalty for not centralizing all SNF in one location. It is for this reason that considerable attention is given to scaling.

Explanation of Scaling Exponents

Exact scaling involves a complex assessment of fixed and variable costs. Typically, approximations are used to facilitate cost estimates. A common equation used for scaling facility costs is as follows (Reference C-1):

$$S_2/S_1 = (C_2/C_1)^R$$

where

- S_1 and S_2 are the costs for the known and scaled facilities, respectively,
- C_1 and C_2 are the capacities for the known and scaled facilities, and
- R is the scaling exponent.

This approximation is valid only within certain scaling ranges or certain facility capacities, perhaps one order of magnitude. Use of a given scaling exponent beyond its range of applicability results in larger uncertainty in the results. The scaling exponents developed here may be less accurate for sites with very small quantities of SNF, primarily under the Decentralization alternative.

Spent Nuclear Fuel Management Activity, Function, or Facility Scaling

The scaling exponents typically used for production facilities within the chemical process industry are in the range of 0.6 to 0.7 (Reference C-1). The DOE SNF management facilities are considerably different than chemical industry production facilities, and the scaling exponents may be considerably different than 0.6 or 0.7 for several reasons:

- Spent nuclear fuel management facilities often include extensive shielding and remote operations, which have associated high fixed costs. These costs are largely independent of capacity.
- DOE SNF facilities are not production-scale facilities; therefore, the chemical industry scaling exponents may not be applicable.
- The SNF processing facilities contain unique processes. Therefore, there will be disproportionately high R&D costs that are largely fixed, rather than variable.
- Modular dry SNF storage facilities are sized by the addition of more modules. This results in a cost-capacity relationship that is nearly directly proportional to capacity.

Scaling factors were calculated for those SNF activities for which there was sufficient data, and the results are presented in Table C-1. The following paragraphs provide a brief description of those SNF activities for which scaling exponents were calculated. The costs reported in the source documents discussed below have varying bases regarding inflation, discounting, etc., and are not appropriate for direct comparison with the results of this cost evaluation.

These limited data points result in scaling exponents that generally range from 0.1 to 0.6 with an average of approximately 0.3 for SNF management facilities. This is consistent with the scaling exponents developed for DOE radioactive waste management, which are also in the 0.3 to 0.4 range. This cost evaluation utilizes the calculated average (rounded to 0.3) of scaling exponents in Table C-1 as its reference value and considers alternative values in the sensitivity section.

Monitored Retrievable Storage Complex (MRS) - DOE developed cost estimates for a monitored retrievable storage (MRS) for commercial power reactor SNF as part of the MPC Conceptual Design Report (CDR) (Reference C-2). Two sizes of MRS were considered in this report: a 900 MTU capacity at a total development and O&M cost of \$825M and a 5,000 MTU capacity at a total development and O&M cost of \$1,283M. These values produce a scaling exponent of 0.26. There are also cost estimates for a number of different storage technologies in the MPC CDR (Reference C-3).

Table C-1. Summary of Scaling Exponent Calculations

Item	Cost 1 (\$M)	Size 1	Cost 2 (\$M)	Size 2	Scaling Exponent
		MTU ¹		MTU	
MPC MRS CDR (Ref. C2)	\$1,283	5,000	825	900	0.26
MPC MRS CDR (Ref. C3)		MTU		MTU	
Concrete Cask Storage	\$904	1,000	\$1,099	5,000	0.12
Wet Storage	\$886	1,000	\$943	5,000	0.04
Vault Storage	\$959	1,000	\$1,366	5,000	0.22
Horizontal Module Storage	\$906	1,000	\$1,185	5,000	0.17
Metal Cask Storage	\$964	1,000	\$1,492	5,000	0.27
TSC Storage	\$957	1,000	\$1,758	5,000	0.38
IAEA SNF Storage Study (Ref. C4)		MTU		MTU	
Upper bound cost	\$298	500	\$640	2,000	0.55
Dry Cask, away-from-reactor	\$260	500	\$440	2,000	0.38
Characterization & Canning (Ref. C5)		MTIHM ²		MTIHM	
Total Project Cost	215	25	309	250	0.16
O&M	63	25	188	250	0.48
D&D	19	25	25	250	0.13
Total w/20 years operations	\$1,488	25	\$4,087	250	0.44
Modular Dry Vault Storage (Ref. C5)		MTIHM		MTIHM	
Total Project Cost	52	17.5	197	175	0.58
O&M (Loading and Unloading Period)	23	17.5	54	175	0.37
O&M-(Storage Period)	12	17.5	24	175	0.32
D&D	2	17.5	8	175	0.59
Total w/20 years operations	\$403	17.5	\$992	175	0.39
SNF Prefab Dry Storage (Ref. C5)		MTIHM		MTIHM	
Total Project Cost	48	7.5	287	75	0.78
O&M (Loading and Unloading Period)	41	7.5	146	75	0.55
O&M-(Storage Period)	6	7.5	8	75	0.12
D&D	0.2	7.5	2	75	0.97
Total w/20 years operations	\$522	7.5	\$1,823	75	0.54
SNF Pool Storage (Ref. C5)		Fuel Elements		Fuel Elements	
Total Project Cost	234	180	308	1,800	0.12
O&M (Loading and Unloading Period)	108	180	170	1,800	0.20
O&M-(Storage Period)	4	180	6	1,800	0.24
D&D	20	180	27	1,800	0.12
Total w/20 years operations	\$1,370	180	\$2,091	1,800	0.18
Average Scaling Exponent					0.30

Footnotes for Table C-1:

1. MTU Metric Tons Uranium
2. MTIHM Metric Tons Initial Heavy Metal

IAEA Storage Cost - The International Atomic Energy Agency has evaluated SNF storage costs for a variety of storage technologies (Reference C-4).

DOE Cost Study - This report (Reference C-5) provides a cost estimate for a number of SNF management facilities of different sizes.

Uncertainty

The uncertainty in the scaling exponents presented in this Appendix is because of limited existing data. Due to this uncertainty, a sensitivity study was performed (Section 8) to assess the impact of variations in the scaling exponent. The cost evaluation has adequately addressed this significant parameter by estimating the facility-specific scaling exponents, developing composite scaling exponents, and assessing the sensitivity of results to this parameter.

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APPENDIX D

FACILITY CAPACITY REQUIREMENTS

APPENDIX D: FACILITY CAPACITY REQUIREMENTS

The SNF data used for the *SNF & INEL EIS* has been enhanced with information regarding the future location of each fuel for each alternative, RCRA characteristics, fuel category (53 categories related to enrichment, cladding, fuel matrix, etc.), condition of current storage facility, candidate process to be used in those strategies that include processing, MPC equivalent storage requirement, etc.. This information was used to determine the facility requirements for each site under each alternative. Table D-1 provides a summary of these requirements in terms of the capacity factor relative to total requirement for that activity. The MPC capacity factor is used for scaling the new facility costs for all Storage Only and Direct Disposition strategies. For the Processing strategy, the building-specific capacity factors are presented. These requirements, in conjunction with the scaling factors, were used to calculate new facility costs in the cost evaluation.

There are some revisions to these requirements that would make sense technologically but have not been included in this cost evaluation. Rather than build facilities to process very small quantities of different fuel types at the same site, one common facility would be utilized to handle multiple fuel types sequentially. Alternatively, small amounts of SNF from one site could be shipped to another site that has more of that SNF type. These refinements would decrease the cost penalty associated with the more distributed alternatives (e.g., Decentralization).

Table D-1. Facility Capacity as a Fraction of Generic Facilities (in percentage)

	MPC ¹	MTHM	Na-Bonded RCRA	Graphite RCRA	Electrolytic	Fluorine ¹	Graphite	LEU	Special	Blending & Separation
1. No Action										
Hanford	25.07%	77.32%	0.20%	0.00%	0.00%	0.00%	0.00%	87.59%	10.53%	44.94%
INEL	23.19%	10.91%	99.65%	42.02%	72.09%	21.62%	41.38%	3.56%	82.24%	18.49%
SRS	9.90%	7.30%	0.04%	0.00%	9.30%	4.05%	0.00%	7.70%	2.63%	6.33%
ORS	0.57%	0.15%	0.00%	0.01%	0.00%	0.00%	3.45%	0.00%	1.97%	0.78%
NTS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Other	41.28%	4.32%	0.10%	57.96%	18.60%	74.32%	55.17%	1.16%	2.63%	29.45%
2A/2B/2C. Decentralization										
Hanford	25.07%	77.31%	0.20%	0.00%	0.00%	0.00%	0.00%	87.59%	10.52%	44.94%
INEL	27.43%	11.13%	99.66%	42.02%	77.68%	21.62%	41.38%	3.56%	82.83%	18.92%
SRS	17.15%	7.77%	0.04%	0.00%	19.71%	4.05%	0.00%	7.74%	4.60%	10.98%
ORS	0.57%	0.15%	0.00%	0.01%	0.00%	0.00%	3.45%	0.00%	1.97%	0.78%
NTS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
BNL	2.57%	0.06%	0.00%	0.32%	2.03%	0.00%	0.00%	0.00%	0.00%	0.42%
LANL	0.01%	0.00%	0.00%	0.00%	0.10%	0.00%	0.00%	0.00%	0.00%	0.02%
SNL	0.02%	0.02%	0.10%	0.00%	0.41%	0.00%	0.00%	0.00%	0.06%	0.11%
ANL-E	0.00%	0.00%	0.00%	0.00%	0.07%	0.00%	0.00%	0.00%	0.00%	0.02%
B&W	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%
Lynchburg										
WVDP	0.22%	0.98%	0.00%	0.00%	0.00%	0.00%	0.00%	1.12%	0.00%	6.55%
5 NNPP Sites	23.07%	1.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.55%
FSVR	3.89%	0.58%	0.00%	57.96%	0.00%	0.00%	55.17%	0.00%	0.00%	3.88%
3. 1992/1993 Planning Basis										
Hanford	25.05%	77.31%	0.20%	0.00%	0.00%	0.00%	0.00%	87.55%	10.53%	44.94%
INEL	57.16%	14.75%	99.75%	100.00%	80.23%	95.95%	96.55%	4.67%	82.89%	43.15%
SRS	17.80%	7.93%	0.04%	0.00%	19.77%	4.05%	3.45%	7.78%	6.58%	11.91%
ORS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
NTS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Other	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4A. Regionalization by Fuel Type										
Hanford	23.56%	76.25%	0.00%	0.00%	0.00%	0.00%	0.00%	87.01%	0.00%	44.32%
INEL	50.24%	16.22%	100.00%	100.00%	70.11%	100.00%	100.00%	5.63%	97.37%	42.59%
SRS	26.20%	7.53%	0.00%	0.00%	29.89%	0.00%	0.00%	7.36%	2.63%	13.09%
ORS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
NTS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Other	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4B. Regionalization by Geography - INEL & SRS										
Hanford	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
INEL	79.45%	91.03%	99.90%	100.00%	78.16%	95.95%	96.55%	91.10%	93.42%	87.17%
SRS	20.55%	8.97%	0.10%	0.00%	21.84%	4.05%	3.45%	8.90%	6.58%	12.83%
ORS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
NTS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Other	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5A/B/C/D/E. Centralization										
Central Site	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

1. Applies for all storage, canning characterization, and repository fees.

APPENDIX E

COST RESULTS

APPENDIX E: COST RESULTS

The cost estimates for each alternative are presented in Table E-1 for each of the management strategies. Results here are presented in constant year dollars (1995\$). The upper row for each scenario represents the Upper Cost Range, with maximum use of new facilities. The lower row for each scenario represents the Lower Cost Range with maximum use of existing facilities.

Table E-1. Cost Results (billions 1995\$)

Scenario		Storage Only	Direct Disposal	Processing
1	No Action	17.4	N.A.	N.A.
		10.6	N.A.	N.A.
2A	Decentralization - No Exam	17.9	29.6	29.5
		8.6	20.2	23.7
2B	Decentralization - Limited Exam	18.1	29.8	29.8
		8.9	20.5	24.0
2C	Decentralization - Full Exam	20.1	31.9	31.8
		10.8	22.5	26.0
3	1992/1993 Planning Basis	18.0	25.5	24.4
		9.4	16.9	21.0
4A	Regionalization by Fuel Type	17.6	24.9	24.1
		9.1	16.0	19.5
4B	Regionalization by Geography	16.0	23.2	23.9
		9.6	18.1	20.6
5A	Centralization at Hanford	15.4	21.7	23.0
		13.5	19.0	20.3
5B	Centralization at INEL	13.8	20.1	20.8
		11.9	17.4	18.2
5C	Centralization at SRS	15.1	21.4	22.6
		9.5	18.8	15.2
5D	Centralization at ORR	17.1	22.6	27.9
		15.1	20.5	24.3
5E	Centralization at NTS	17.5	22.9	28.4
		15.3	20.8	24.6

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APPENDIX F

REPOSITORY EXPENSE BASIS

APPENDIX F: REPOSITORY EXPENSE BASIS

This appendix documents the basis of unit cost estimates for disposal of DOE SNF.

UNIT DISPOSAL COST

Storage costs are being addressed for each of the *SNF & INEL EIS* alternatives and are the primary focus of the Cost Evaluation. There is no established methodology for calculating the disposal fee for DOE SNF, and any one of several approaches could be taken (e.g., fees based on MPC count, volume, heavy metal content, or decay heat). This Cost Evaluation uses a fee based on the unit cost (per MPC) for commercial SNF. This approach was selected because it provides a common basis for DOE SNF and commercial SNF, it utilizes DOE Office of Civilian Radioactive Waste Management (OCRWM) cost estimates directly, and the necessary DOE SNF data are already available.

Note: A methodology was developed for calculating DOE defense waste fees. The Defense Waste methodology is complicated, may not be relevant for DOE SNF because of the difference in waste form and packaging, and therefore, was not used for this evaluation (Reference F-1).

REPOSITORY COSTS

Table F-1 presents the repository costs for disposing commercial SNF. The values in the table come from two OCRWM documents: repository expense estimates developed in 1989 (Reference F-2) and 1994 estimates of MPC costs (Reference F-3). This Cost Evaluation used the values in the table as the basis for estimating repository costs for DOE SNF.

As the table shows, the unit disposal cost for commercial SNF includes repository development and evaluation, procurement of MPCs, transportation to the repository, repository operating expenses (both above and below ground), MRS expenses, and benefit payments. A credit is given for costs associated with defense high level waste (HLW), since defense waste is managed under a separate program but had been included in the OCRWM estimates for total repository expenses. The MRS costs for commercial SNF is excluded from the commercial total to arrive at an estimate unit cost applicable to DOE SNF.

The report on commercial disposal fees (DOE/RW-0295P) estimated the total system cost for the two-repository situation to be \$33.64B in 1988 dollars (including costs associated with defense HLW). Subtracting the MRS facility expenses (\$1.613B) and defense waste allocation (\$5.759B) from that arrives at a total repository expense applicable for DOE SNF of \$26.268B. Inflating this to 1995 dollars (assuming an average of 4% inflation for 7 years) results in an estimated cost of \$34.6B (1995\$) for DOE SNF repository expenses. Additional expenses associated with the use of multi-purpose canisters (MPC) is discussed below.

Table F-1. Repository Cost Breakdown for Commercial SNF

Description	Reference	Total Cost		Unit Cost ¹
		(Reported \$M)	(1995\$M)	
Repository Development & Evaluation	DOE/RW-0295W Table 1-1	\$15,033	\$ 19,782	\$ 1.917
Transportation to Repository	DOE/RW-0295W Table 1-1	\$ 2,658	\$ 3,498	\$ 0.339
First Repository	DOE/RW-0295W Table 1-1	\$ 6,992	\$ 9,201	\$ 0.892
Second Repository	DOE/RW-0295W Table 1-1	\$ 6,551	\$ 8,621	\$ 0.835
MRS Facility (for commercial SNF) ²	DOE/RW-0295W Table 1-1	-	-	-
Benefits Payments ³	DOE/RW-0295W Table 1-1	\$ 793	\$ 1,044	\$ 0.101
Defense Waste Allocation (HLW glass)	DOE/RW-0295W Table 1-1	\$(5,759)	\$(7,578)	\$(0.734)
MPC Adjustments: (subtotal = \$1.713B)				
Containers (MPCs)	DOE/RW-0445 Table ES-2	\$ 4,570	\$ 4,943	\$ 0.479
Waste Acceptance Equipment	DOE/RW-0445 Table ES-2	\$ 27	\$ 29	\$ 0.003
Transportation (delta for MPCs)	DOE/RW-0445 Table ES-2	\$(282)	\$(305)	\$(0.030)
First/Second Repository (delta for MPCs)	DOE/RW-0445 Table ES-2	\$(2,602)	\$(2,814)	\$(0.273)
		\$ 27,981	\$ 36,420	\$ 3.529

1. Unit costs are per MPC.
 2. MRS facility costs of \$1,613 (1988\$) would not be part of the DOE fee and are excluded here.
 3. Benefit payments are fees paid to the repository host state.

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MPC COSTS

The OCRWM repository estimate (Reference 3) was produced before the MPC concept was developed. The later OCRWM evaluation of MPCs increases expected costs for commercial SNF by \$1.7B (Reference F-4) (see Table F-1).

The total commercial SNF inventory can be placed into 5,768 large 125-ton PWR (pressurized water reactor) MPCs, 3,333 large 125-ton BWR (boiling water reactor) MPCs, 698 small 75-ton PWR MPCs, and 1,367 small 75-ton BWR MPCs. The \$36.4B total for MPC commercial expenses was arrived at by converting the small MPCs to a large MPC equivalent and ignoring the cost savings associated with use of the larger MPCs. The conversion of small canisters to large adds another 1,219 large MPCs to (399 PWR and 820 BWR) for a total of 10,320 large MPCs needed to contain commercial SNF. Therefore, the one repository unit cost is \$3.5M (1995\$) per large MPC (\$36.4B for 10,320 MPCs). This cost includes procurement of MPCs, transportation to the repository, development and evaluation of the repository, and repository operations (above and below ground).

NUMBER OF MPCs FOR DOE SNF

The number of MPCs required for disposal of DOE SNF is estimated at 1065. This is based on volumetric loading using the large (125-ton) MPCs. Special inserts may be needed for some DOE fuel types.

TOTAL DISPOSAL COST FOR DOE SNF

The total cost for MPC procurement, MPC transportation, disposal, and share of repository development and evaluation for DOE SNF is \$3.7B (1995\$). This cost does not include storage, waste form qualification for the numerous fuel types, SNF characterization, MPC loading, etc. A number of factors could increase costs, e.g., if the waste acceptance criteria are unfavorable, the MPC concept is not approved, more robust MPCs are required, or repository development costs increase from the 1999 estimate.

This evaluation does not consider MPC loading limits that may be more restrictive than the volumetric limits. More restrictive loading limits could significantly increase the number of MPCs required.

REFERENCES

- F-1. U.S. Department of Energy Office of Civilian Radioactive Waste Management, Civilian Radioactive Waste Management, *Calculating Nuclear Waste Fund Disposal Fees for Department of Energy Defense Program Waste*; Notice, Federal Register Part V, August 20, 1987.
- F-2. U.S. Department of Energy, *Preliminary Estimates of the Total-System Cost for the Restructured Program: An Addendum to the May 1989 Analysis of the Total-System Life Cycle Cost for the Civilian Radioactive Waste Management Program*, DOE/RW-0295P, December 1990.
- F-3. U.S. Department of Energy Office of Civilian Radioactive Waste Management, *Multi-Purpose Canister System Evaluation, A Systems Engineering Approach*, DOE/RW-0445, September 1994.
- F-4. TRW Environmental Safety Systems, Inc., *Life-Cycle Cost Comparison for the Multi Purpose Canister System*, Revision 0, December 10, 1993.
- F-5. A. Lopez, EG&G Idaho, Inc., *MPC Quantity And Cost Estimates For The Complex-Wide EIS*, DAL-11-94, June 14, 1994.
- F-6. R.A. Guida, U.S. Department of Energy, NE-60 letter to Jill Lytle, EM-30, *Naval Reactors Input to Spent Fuel Management Cost Report*, October 7, 1994.