**Office of
Fissile Materials
Disposition**

United States Department of Energy

***SUMMARY REPORT OF
THE SCREENING
PROCESS***

**TO DETERMINE REASONABLE ALTERNATIVES
FOR
LONG-TERM STORAGE AND DISPOSITION OF
WEAPONS-USABLE FISSILE MATERIALS**

**TO BE CARRIED FORWARD FOR
DETAILED STUDY UNDER THE NATIONAL ENVIRONMENTAL POLICY ACT
AND
DETAILED TECHNICAL, ECONOMIC AND NONPROLIFERATION ANALYSIS**

MARCH 29, 1995

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401.

Available to the public from the U.S. Department of Commerce, Technology Administration, National Technical Information Service, Springfield, VA 22161.
(703) 487-4650.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

FOREWORD

The *Screening Process Summary Report* is the result of an eight-month effort to identify and evaluate potentially viable options for long-term storage and disposition of weapons-usable fissile materials. This report summarizes the screening criteria that were utilized, the options that were considered, and the results of the screening evaluations which establish the reasonable alternatives that should be carried forward for detailed environmental analyses under the National Environmental Policy Act and the detailed technical, schedule, economic and nonproliferation assessments to identify preferred alternatives in the Environmental Impact Statements and subsequently support Records of Decision.

Howard R. Canter, Chair
Technical Director
Office of Fissile Materials Disposition

Greg Rudy
Acting Director
Office of Fissile Materials Disposition

J. David Nulton
Director, NEPA Compliance and Outreach
Office of Fissile Materials Disposition

Andre I. Cygelman
Deputy Technical Director
Office of Fissile Materials Disposition

Patrick T. Rhoads
General Engineer
Office of Fissile Materials Disposition

Randall M. Erickson, Executive Secretary
Technical Advisor
Office of Fissile Materials Disposition

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *u/w*

MASTER

Table of Contents

1.	Introduction and Executive Summary	1-1
1.1.	Introduction	1-1
1.2.	Public and Stakeholder Involvement	1-3
1.3.	The Spent Fuel Standard.....	1-4
1.4.	Screening Criteria	1-4
1.5.	Options Considered	1-5
1.6.	Screening Evaluation Process	1-6
1.7.	Summary of Results	1-8
1.7.1.	Long-Term Storage of National Security Inventory Materials	1-8
1.7.2.	Disposition of Surplus Plutonium	1-9
1.7.3.	Disposition of Surplus Highly Enriched Uranium	1-12
1.7.4.	Disposition of Surplus Uranium-233 and Other Minor Actinides	1-13
2.	Criteria for Screening Long-Term Storage and Disposition Options	2-1
2.1.	Introduction	2-1
2.2.	Criteria Descriptions	2-7
3.	Options Considered in the Screening Process	3-1
3.1.	Determination of Long-Term Storage Options	3-1
3.2.	Determination of Surplus Plutonium Disposition Options	3-2
3.2.1.	Plutonium Available for Disposition	3-2
3.2.2.	Plutonium Disposition Options	3-3
3.3.	Determination of Surplus Highly Enriched Uranium Options	3-5
3.4.	Determination of Surplus U-233 and Other Minor Actinide Disposition Options	3-6
4.	Summary of Results	4-1
4.1.	Screening of Long-Term Storage Options	4-1
4.1.1.	Introduction	4-1
4.1.2.	Baseline Alternative for Long-Term Storage	4-1
4.1.3.	Options Determined to be Reasonable for Long-Term Storage	4-2
4.1.4.	Long-Term Storage Option Rated but Eliminated from Further Consideration	4-3
4.1.5.	Long-Term Storage Option Disqualified from Further Consideration	4-3

4.2.	Screening of Plutonium Disposition Options	4-4
4.2.1.	Introduction	4-4
4.2.2.	Baseline Option for Plutonium Disposition	4-4
4.2.3.	Options Determined to be Reasonable for Plutonium Disposition	4-6
4.2.4.	Plutonium Disposition Options Rated but Eliminated from Further Consideration	4-8
4.2.5.	Plutonium Disposition Options Disqualified Prior to Rating	4-10
4.3.	Screening of Highly Enriched Uranium Disposition Options	4-13
4.3.1.	Introduction	4-13
4.3.2.	Baseline Option for HEU Disposition	4-14
4.3.3.	Options Determined to be Reasonable for HEU Disposition	4-14
4.3.4.	HEU Disposition Options Rated but Eliminated from Further Consideration	4-15
4.4.	Screening of U-233 and Other Minor Actinide Disposition Options	4-17
4.4.1.	Introduction	4-17
4.4.2.	Baseline Alternative for U-233 Disposition	4-18
4.4.3.	Options Determined to be Reasonable for U-233 Disposition	4-19
4.4.4.	U-233 Disposition Options Rated but Eliminated from Further Consideration	4-19
4.4.5.	U-233 Disposition Option Disqualified Prior to Rating	4-20
A.	Public and Stakeholder Involvement	A-1
A.1.	Summary of Public Input	A-1
A.2.	Impacts of Public Input on Screening Criteria	A-3
A.3.	Long-Term Storage Screening Criteria Questionnaire	A-4
A.4.	Disposition Screening Criteria Questionnaire	A-14
B.	Spread Sheet of Plutonium Disposition Options	B-1
C.	Screening Committee Members	C-1

List of Figures

1-1.	Evaluations Leading to Records of Decision	1-3
1-2.	Screening Evaluation Process	1-7
1-3.	Summary of Screening Results for Long-Term Storage	1-8
1-4.	Summary of Screening Results for Plutonium Disposition	1-11
1-4.	Summary of Screening Results for Highly Enriched Uranium Disposition	1-12
1-6.	Summary of Screening Results for Uranium-233 Disposition	1-14
4-1.	Relative Ratings among Long-Term Storage Options	4-2
4-2.	Relative Ratings among Plutonium Disposition Options	4-5
4-3.	Relative Ratings among HEU Disposition Options	4-14
4-4.	Relative Ratings among Uranium-233 Disposition Options	4-18

List of Tables

2-1a.	Screening Criteria for Long-Term Storage	2-3
2-1b.	Screening Criteria for Disposition	2-3
2-2.	Criteria and Factors	2-4
2-3.	Potential Disqualifiers or Fatal Flaws	2-5
3-1.	Plutonium Chemical and Physical Forms Likely to be Declared Surplus	3-3

SECTION 1. INTRODUCTION AND EXECUTIVE SUMMARY

1.1. INTRODUCTION

Significant quantities of weapons-usable fissile materials (primarily plutonium and highly enriched uranium) have become surplus to national defense needs both in the United States and Russia. These stocks of fissile materials pose significant dangers to national and international security. The dangers exist not only in the potential proliferation of nuclear weapons but also in the potential for environmental, safety and health consequences if surplus fissile materials are not properly managed.

In September 1993, President Clinton announced the establishment of a framework for U.S. efforts to prevent the proliferation of weapons of mass destruction. This policy commits the United States to undertake a comprehensive approach to the growing accumulation of fissile materials from dismantled nuclear weapons. As key elements of the President's policy, the United States will:

Seek to eliminate, where possible, the accumulation of stockpiles of highly enriched uranium or plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security, and international accountability.

Pursue the purchase of highly-enriched uranium from the former Soviet Union and other countries and its conversion to peaceful use as reactor fuel.

Initiate a comprehensive review of long-term options for plutonium disposition, taking into account technical, nonproliferation, environmental, budgetary and economic considerations. Russia and other nations with relevant interests and experience will be invited to participate in the study.

The contexts for these policy initiatives vary substantially in the U.S. and Russia. In the U.S., the current environmental, safety and health (ES&H) vulnerabilities have been recently identified,¹ and a corrective action plan is being finalized. These corrective actions are planned to result in a safe, secure and inspectable interim storage condition within approximately eight years. This represents the baseline for evaluation of options for long-term storage and disposition of U.S. weapons-usable fissile materials.

In Russia, there are ES&H vulnerabilities associated with fissile material storage as well. However, there are also safeguards and security vulnerabilities that stem from limited nuclear material accountability systems coupled with concerns that institutional controls may weaken with time. The near-term U.S. initiatives to help the Russians deal with these problems are focused on instituting state-of-the-art material control and accountability technologies and practices, and constructing new facilities to store retired nuclear weapon components.

In parallel with these efforts, the U.S. and Russian governments are jointly studying options for the disposition of weapons-usable fissile materials to reduce the reliance on institutional controls and provide assurance to the international community that the recent arms reductions will not be reversed. While some argue that the international security risks are not dramatically improved by the disposition of U.S. weapons-usable materials because the materials can be adequately protected in storage, it is clear that international progress requires U.S.-Russian bilateral reductions. Therefore, disposition actions are needed on an urgent basis to minimize the time period that these materials remain in weapon-usable form.

¹U.S. Department of Energy, DOE/EH-0415, "Plutonium Working Group Report on Environmental, Safety and Health Vulnerabilities Associated with the Department's Plutonium Storage," November, 1994.

As announced in the Notice of Intent (NOI) to prepare a Programmatic Environmental Impact Statement (PEIS),² the Department of Energy is currently conducting an evaluation process for

- Disposition³ of surplus weapons-usable fissile materials determined surplus to National Security needs, and
- Long-term storage⁴ of national security and programmatic inventories, and surplus weapons-usable fissile materials that are not able to go directly from interim storage to disposition.

The scope of this evaluation includes the disposition of approximately 50 MT of surplus U.S. weapons-usable plutonium⁵ and a greater quantity of surplus highly-enriched uranium (HEU). Minor actinides and surplus U-233 are also being reviewed. A recent National Academy of Sciences Report⁶ provided a similar evaluation framework and information relating to plutonium disposition options.

Subsequent to issuing the NOI, as a result of the public scoping process, the Department has concluded that the nature of potential HEU disposition actions and the reasonable alternatives for these actions warrant a separate and distinct Environmental Impact Statement. The PEIS will address the long-term storage of all the above materials and the disposition of surplus plutonium, U-233 and minor actinides.

Even though there are significant quantities of plutonium contained in spent fuel, these inventories are not included in this evaluation because the spent fuel has inherent barriers that already reduce the reliance on institutional controls. Although the radiation barrier associated with spent fuel decays with time, there is a path forward established by the Nuclear Waste Policy Act for disposal of spent fuel in a mined geologic repository, where geologic barriers will reduce the reliance on institutional controls. Therefore, spent fuel represents an acceptable standard for disposition actions.

Figure 1-1 illustrates that the purpose of the screening process is to consider potential options and to identify reasonable alternatives for a subsequent detailed evaluation to support Records of Decision. (Throughout this document, the term “option” will be used for all approaches considered in the screening process, and “reasonable alternatives” for those that are to be carried forward for detailed evaluation.) The detailed evaluation will be a thorough assessment of the reasonable alternatives in the two NEPA documents, along with a parallel technical, economic and non-proliferation analysis process, which will determine preferred alternatives and ultimately support Records of Decision.

² Federal Register, Vol. 59, No. 118, June 21, 1994, p. 31985 - 31990.

³ Disposition refers to making the material substantially and inherently more proliferation-resistant than its current form.

⁴ Long Term Storage implies a facility and infrastructure that would be viable for at least 50 years and meet the same safeguards and security standards used for storage of nuclear weapons.

⁵ Plutonium-238 used in deep space missions and plutonium contained in spent fuel and other waste forms are not considered to be weapons-usable and therefore not within the scope of the PEIS.

⁶ National Academy of Sciences, Committee on International Security and Arms Control, Management and Disposition of Excess Weapons Plutonium, National Academy Press, Washington, DC., 1994.

Figure 1-1. Evaluations Leading to Records of Decision

A decision to commence implementation of surplus weapons-usable fissile materials disposition will be made on a broad domestic and international context taking into account any arrangements or agreements reached with the Russian government. This decision will involve other Executive branch agencies in addition to the Department of Energy. The Department's technical efforts and analysis and its Record of Decision will provide the essential foundation to afford the U.S. Government the credible basis and flexibility to enter into negotiations on bilateral or multilateral actions to disposition surplus weapons-usable fissile material inventories, or to implement disposition options unilaterally as a practical demonstration for other nations.

1.2. PUBLIC AND STAKEHOLDER INVOLVEMENT

In conducting this screening process, DOE obtained public input on screening criteria to be utilized and options to be evaluated as part of the public scoping process. As an initial step in the NEPA process and as announced in the NOI, a series of 12 Scoping Meetings were held at twelve locations across the country from August to October 1994. Members of the interested public were briefed by DOE on the overall long-term storage and disposition considerations, criteria, and evaluation process, including the proposed screening process. During these meetings, questionnaires were provided for public input on (1) validity and relative importance of the criteria, and (2) additional criteria that should be considered. Responses received were evaluated, and modifications to the criteria were made, as summarized in Appendix A of this report.

The proposed screening criteria included a proposed time frame for action: that the disposition technology be demonstrated within 20 years and disposition completed within 50 years. There was a strong response from this external involvement relating to the urgency of taking action stemming from the "clear and present danger" associated with these materials. The screening criteria were modified to reflect this sense of urgency to minimize the time period that surplus fissile materials remain in weapons-usable form, and require that the disposition be able to start within about a decade and be able to be completed within about three decades.

1.3. THE SPENT FUEL STANDARD

The primary goal of disposition is to render weapons-usable fissile materials inaccessible and unattractive for weapons use while protecting human health and the environment. In its report, the National Academy of Sciences recommended that plutonium disposition strategies endeavor to attain the “spent fuel standard.” This standard would require a form from which extraction and use in weapons of any residual plutonium and other fissile materials are as difficult or unattractive as the recovery of residual plutonium from spent commercial nuclear fuel. When a disposition strategy achieves this standard, the proliferation risk associated with the residual surplus material is neither unique nor greater than that associated with the much larger inventory of residual plutonium in spent fuel. Achieving this spent fuel standard would result in any residual material being embedded in a highly radioactive matrix, mixed with a variety of other chemical species on a substantially homogeneous basis, and packaged in a large, bulky integral form which provides barriers to use.

Achieving the spent fuel standard provides three significant benefits. First, an increase in the proliferation-resistance is gained by transforming surplus materials into a less accessible form that leads to decreased reliance on institutional barriers to protect the material from theft or diversion. Second, it preserves options for final disposition after achieving the spent fuel standard such as the ultimate emplacement in a high-level waste repository. Third, achieving the spent fuel standard for weapons-usable fissile materials demonstrates to the world the United States’ commitment to nonproliferation and irreversible arms reduction by making the fissile material no more attractive for weapons reuse than the larger inventory of spent commercial nuclear fuel.

One component of proliferation resistance is provided by the form of material, e.g., bulk, weight, and radiation field. Two other components relate to the environment in which the fissile material is located (such as a vault or a geologic repository) and to the safeguards and security applied to the material. By itself, achieving the spent fuel standard does not afford sufficient proliferation resistance; the material must still be properly located and/or properly safeguarded. Furthermore, it is possible that sufficient proliferation resistance can be achieved without embedding the material in a highly radioactive matrix, such as emplacement in a deep borehole where geologic location imposes a barrier against clandestine retrieval of the material.

As part of the public scoping process, the Department of Energy solicited input on the adequacy of the spent fuel standard as a basis for disposition actions. Although there was some concern regarding the lack of a precise quantification and questions on how the standard would apply to non-reactor options, there was a general acceptance of the spent fuel standard concept (except for proponents of developmental technologies that could go beyond the spent fuel standard).

As a result of the screening process, the concept of disposition actions achieving the spent fuel standard as an appropriate degree of proliferation resistance was re-affirmed. This was a result of evaluating options against the full set of criteria and determining that the greater degree of proliferation resistance provided by technologies that go beyond the spent fuel standard were individually determined to be not worth the substantial additional time and cost required. In light of the significant quantities of plutonium that are already contained in spent fuel, and the path forward for disposal of those forms meeting the spent fuel standard established by the Nuclear Waste Policy Act, the Spent Fuel Standard is considered adequate.

1.4. SCREENING CRITERIA

Screening criteria were developed based on the policy objectives articulated in the President's Nonproliferation and Export Control Policy of September 1993 and the January 1994 “Agreement between the United States and Russia on Nonproliferation of Weapons of Mass Destruction and their Means of Delivery,” as well as the analytical framework established by the National Academy

of Sciences in their study on disposition of surplus plutonium. Based on input from the public on a proposed set of screening criteria, the following criteria were used for rating individual options:

For Long-Term Storage

1. Resistance to Theft and Diversion by Unauthorized Parties
2. Technical Viability
3. Environment, Safety, and Health
4. Cost Effectiveness
5. Timeliness
6. Fosters Progress and Cooperation with Russia and Others
7. Public and Institutional Acceptance

For Disposition

1. Resistance to Theft and Diversion by Unauthorized Parties
2. Resistance to Retrieval, Extraction, and Reuse by the Host Nation
3. Technical Viability
4. Environment, Safety, and Health
5. Cost Effectiveness
6. Timeliness
7. Fosters Progress and Cooperation with Russia and Others
8. Public and Institutional Acceptance
9. Additional Benefits

These criteria and the underlying factors that influence the criteria are discussed in Section 2 of this report. Most of the criteria contain a "potential disqualifier" statement which describes a "fatal flaw" that would result in an option being disqualified prior to being rated in the evaluation process.

1.5. OPTIONS CONSIDERED

An option is an approach which identifies how a storage or disposition strategy might be implemented in a systematic, cradle-to-grave manner. Options were identified for a baseline approach and perturbations from the baseline were identified as possible variants to the option. The degree of perturbation that might be accommodated within an option before the option becomes substantially different is a matter of judgment. As the option definition process proceeded, some variants became options, and some initial options were determined to be variants of other options.

Based on a review of the National Academy of Sciences report,⁷ prior DOE-sponsored work on high level waste disposal,⁸ and input from the public obtained during the scoping process, an extensive set of long-term storage and disposition options was compiled.

Five broad long-term storage options were identified:

- 1- The No Action Alternative (leave the weapons-usable materials in interim storage facilities).
- 1- Upgrade of interim storage facilities to allow for some consolidation to reduce the number of storage sites.
- 1- Consolidation of the weapons-usable fissile materials at a DOE site.
- 1- Utilization of any existing facilities at non-Department-of-Energy domestic sites.
- 1- Utilization of non-domestic sites for long-term storage.

⁷ibid.

⁸U.S. Department of Energy, DOE/EIS-0046F, "Management of Commercially Generated Radioactive Waste," October, 1980.

Thirty-seven options were considered for plutonium disposition:

- 1- No Plutonium Disposition Action (Continued Storage)
- 1- Continued Storage with Enhanced Passive Security
- 13- Disposal (e.g., deep boreholes, subsurface shale or magma, ice caps, oceans, or space)
- 6- Immobilization with Radionuclides; then to Repository or Equivalent
- 16- Consuming Plutonium in a Reactor or Accelerator, then to Repository or Equivalent

Nine options were considered for HEU disposition:

- 1- No HEU Disposition Action (Continued Storage)
- 1- Direct Sale of HEU (with buyer to blend to LEU)
- 1- Disposal
- 1- Immobilization with Radionuclides; then to Repository or Equivalent
- 5- Blending to LEU, then storage, sale, or disposal of the blended product

Eight options were identified for Uranium-233 disposition:

- 1- No U-233 Disposition Action (Continued Storage)
- 2- Blending with U-238, then storage or disposal of the blended product
- 3- Disposal
- 1- Immobilization with Radionuclides; then to Repository or Equivalent
- 1- Reactor Irradiation

Several of the plutonium disposition options could have been analyzed for HEU or U-233 disposition but were not analyzed because they had been determined to be unreasonable for plutonium disposition for reasons that would also make them unreasonable for HEU or U-233 disposition.

1.6. SCREENING EVALUATION PROCESS

The screening evaluation was conducted by a Screening Committee of cognizant Department of Energy officials, assisted by Technical Advisors from the National Laboratories and other support staff (see Appendix C). The evaluations proceeded as follows:

- The evaluation and findings prepared by the National Academy of Sciences⁹ were reviewed for information on those options considered by the NAS.
- Technical summaries of all options were prepared by technical experts from the National Laboratories as an information resource for the screening process.
- Technical briefings were requested for those options requiring amplification, including reviews of (1) the separate evaluation of reactor burning options conducted by DOE;¹⁰ (2) prior evaluations conducted by DOE's Office of Civilian Radioactive Waste Management for high level waste;¹¹ (3) a detailed parallel evaluation of immobilization options conducted by Lawrence Livermore National Laboratory (to be published); and (4) a number of options that were not considered in the National Academy of Sciences study.

⁹National Academy of Sciences, op. cit.

¹⁰U.S. Department of Energy Plutonium Disposition Study, to be published.

¹¹U.S. Department of Energy, DOE/EIS-0046F, op.cit.

- Results of public and stakeholder input were reviewed. Screening criteria were modified and the list of potential options was expanded as a result of this input.
- Options were evaluated against the "potential disqualifiers" to determine if any options had a "fatal flaw" in one or more of the screening criteria.
- Each remaining option was rated either high, medium, or low versus each criterion, relative to the other options.
- Options which rated low for multiple criteria and/or were clearly dominated by similar, more attractive options in the same family were eliminated as unreasonable for detailed evaluation.

Because detailed information is not available for every option, expert professional judgment was exercised based on available information. In using an overall evaluation approach based on multiple low ratings and/or dominance, specific weights of the individual criteria were not necessary.

The screening evaluation process is shown in Figure 1-2.

Figure 1-2. Screening Evaluation Process

1.7. SUMMARY OF RESULTS

The screening results are summarized in Figure 1-3, 1-4, 1-5 and 1-6, which list the options considered in the screening process, whether the options were disqualified, eliminated, or considered to be reasonable for detailed study under NEPA, and the technical, economic and nonproliferation evaluation processes. Principal reasons for disqualification or elimination are shown. Both baseline and reasonable alternatives will be carried forward for detailed evaluation. Section 4 of this report provides a more detailed summary discussion of the results.

1.7.1. Long-Term Storage of National Security Inventory Materials

Figure 1-3 shows the screening results for long-term storage. Two options were selected as reasonable alternatives for further evaluation in the PEIS and in the detailed technical, economic and non-proliferation evaluation process, in addition to the baseline alternative of No Action (continued use of interim storage facilities):

- (LTS-2) Upgrade of interim storage facilities to make them suitable for Long-Term Storage.
- (LTS-3) Consolidation of the weapons-usable fissile materials at DOE sites.

The option that would utilize non-DOE sites (LTS-4) was eliminated in the screening process because of cost-effectiveness, ES&H, and public / institutional acceptance concerns, with no overriding advantages compared to existing DOE sites already safeguarding nuclear materials. It is judged that the public and other Government agencies would express concern over creating another DOE nuclear site when several are being phased out.

Utilization of non-domestic sites (LTS-5) is not able to address all the long-term storage requirements. The long-term storage requirements include the storage of materials set aside as a strategic reserve for defense purposes, which are not appropriate to locate outside the U.S. This option was disqualified because the risk of theft / diversion by unauthorized parties would be greater than those involved in the utilization of domestic sites. Safeguards and security of nuclear material are enhanced by the domestic law enforcement infrastructure, which would not be as easily coordinated outside the U.S.

Figure 1-3. Summary of Screening Results for Long-Term Storage

Legend:	
Disqualified -	Option considered to have fatal flaw in one or more criteria.
Eliminated -	Option rated against all criteria and found to have multiple low ratings or is clearly dominated by other options that achieve similar results.
Reasonable -	Option should be analyzed as a Reasonable Alternative.
Baseline -	The No Action Alternative must be analyzed in PEIS. May or may not be reasonable.

LONG-TERM STORAGE OPTIONS

LTS-1 NO ACTION	Baseline
LTS-2 UPGRADE INTERIM STORAGE FACILITIES	Reasonable
LTS-3 CONSOLIDATE STORAGE AT DOE SITES	Reasonable
LTS-4 UTILIZE FACILITIES AT NON-DOE DOMESTIC SITES	Eliminated (ES&H, Cost-Effectiveness)
LTS-5 UTILIZE NON-DOMESTIC SITES	Disqualified (Higher S&S Risks)

1.7.2 Disposition of Surplus Plutonium

1.7.2.1. Plutonium Disposition Options Determined to be Reasonable Alternatives for Detailed Study:

Figure 1-4 shows the summary of the screening results for plutonium disposition. From the options evaluated, eleven options were selected as reasonable alternatives for further evaluation in the PEIS and detailed technical, economic and non-proliferation evaluation process, in addition to the baseline option of No Plutonium Disposition Action (continued storage):

- (D-2/3) Emplacement in Deep Boreholes (either directly or immobilized without radionuclides, which are separate options)
- (I-3) Immobilization with Radionuclides in a New Borosilicate Glass Vitrification Plant or Facility, with ultimate Repository Disposal
- (I-4) Ceramic Immobilization with Radionuclides, with ultimate Repository Disposal
- (I-5) Electrometallurgical Treatment with Radionuclides, with ultimate Repository Disposal
- (I-6) Borosilicate Glass Oxidation/Dissolution/Immobilization with Radionuclides, with ultimate Repository Disposal
- (R-1) Transfer to the Euratom Market for Mixed Oxide (MOX) Fuel / Reactor Burning
- (R-2) Consuming in Existing U.S. Light Water Reactors, with ultimate Repository Disposal
- (R-2A) Consuming in Partially Completed Light Water Reactors, with ultimate Repository Disposal
- (R-3) Consuming in Evolutionary or Advanced Light Water Reactors, with ultimate Repository Disposal
- (R-6) Consuming in CANDU Heavy Water Reactors, with Spent Fuel Disposal by the Canadian Utility

1.7.2.2. Plutonium Disposition Options Rated but Eliminated:

Twelve options were eliminated based on multiple low rankings and/or dominance by similar, acceptable alternatives discussed above. These are:

- (S-2) Radiation Barrier Alloy (storage with enhanced passive security)

This was eliminated as a disposition option because it did not have an “end-point” destination comparable to other disposition options.
- (I-2) Borosilicate Glass Immobilization using a Modified Defense Waste Processing Facility (DWPF)

This was eliminated because the DWPF was not designed for criticality control, and therefore would require extensive modifications and re-fitting of the facility and equipment during or after its present mission, potentially resulting in increased personnel radiation exposure, along with potential delays and cost escalation for its present mission.
- (D-7) Injection into Continental Magma
- (D-11) Sub-seabed Emplacement
- (D-13) Deep Space Launch

The above three direct disposal options were eliminated because of either technical maturity concerns, ES&H concerns, or both.

- (R-5) Consuming in Modular Helium Reactors
- (R-7) Advanced Liquid Metal Reactors with Pyroprocessing
- (R-8) Accelerator Conversion / Molten Salt Target
- (R-9) Accelerator Conversion / Particle Bed Target
- (R-12) Accelerator-Driven Modular Helium Reactors
- (R-14) Particle Bed Reactors
- (R-15) Molten Salt Reactors

The above fission options (R-series) were eliminated primarily due to their technical immaturity, and attendant costly and lengthy development and demonstration effort required to bring them to a viable, practical status which would enable disposition options to be initiated with certainty. Although these options hold promise of higher levels of plutonium destruction (burn-up) than other reactor burning options (that is, they might go beyond the Spent Fuel Standard), it was judged that, at this time, the increased plutonium burn-up that could be achieved does not counter-balance the cost, schedule or technical risks associated with these options. Since plutonium disposition can be accomplished using existing technologies to achieve the Spent Fuel Standard, there is no justification to develop these advanced technologies solely for the purpose of plutonium disposition. However, if some of these advanced concepts are developed and successfully operated for other missions (such as for commercial nuclear power) they will be considered for plutonium disposition as well.

1.7.2.3. Plutonium Disposition Options Disqualified in the Screening Process

Thirteen options were disqualified from further evaluation because of a "fatal flaw" in meeting a minimum threshold for one or more criteria. These were:

- (D-1) Direct Emplacement (without immobilization) in a High Level Waste Repository
- (D-4) Discard to WIPP of large volumes of surplus plutonium¹²
- (D-5) Hydraulic Fracturing into Subsurface Shale Formations
- (D-6) Injection of Slurries into Deep Wells
- (D-8) Melting in Crystalline Rock
- (D-9) Disposal Under Ice Caps
- (D-10) Seabed Disposal by Emplacement on Ocean Floor
- (D-12) Controlled Dilution in Oceans
- (I-1) Underground Nuclear Detonation
- (R-4) Consuming Plutonium in Naval Propulsion Reactors
- (R-10) Consuming in Light Water Reactors with Reprocessing of Spent Fuel
- (R-11) Consuming in Advanced Light Water Reactors with Reprocessing of Spent Fuel
- (R-13) Consuming in Advanced Liquid Metal Reactors with Recycle and Reuse of Metallic Alloy Fuel Elements (ALMR/IFR concept).

¹²The option to send smaller quantities of transuranic wastes or other minor actinides to WIPP is considered to be reasonable.

Figure 1-4. Summary of Screening Results for Plutonium Disposition

PLUTONIUM DISPOSITION OPTIONS

STORAGE OPTIONS

S1 NO DISPOSITION ACTION (CONTINUED STORAGE)		Baseline
S2 RADIATION BARRIER ALLOY (STORAGE)	Eliminated (Open-Ended, ES&H)	

DISPOSAL OPTIONS

D1 DIRECT EMPLACEMENT IN HLW REPOSITORY	Disqualified (Retrievability, Timeliness)	
D2 DEEP BOREHOLE (IMMOBILIZATION)		Reasonable
D3 DEEP BOREHOLE (DIRECT EMPLACEMENT)		Reasonable
D4 DISCARD TO WIPP	Disqualified (Capacity)	
D5 HYDRAULIC FRACTURING	Disqualified (Technical Viability)	
D6 DEEP WELL INJECTION	Disqualified (ES&H)	
D7 INJECTION INTO CONTINENTAL MAGMA	Eliminated (Technical Viability, ES&H)	
D8 MELTING IN CRYSTALLINE ROCK	Disqualified (Technical Viability, ES&H)	
D9 DISPOSAL UNDER ICE CAPS	Disqualified (Technical Viability, ES&H)	
D10 SEABED (PLACEMENT ON OCEAN FLOOR)	Disqualified (ES&H, Treaty)	
D11 SUB-SEABED EMPLACEMENT	Eliminated (Technical Viability)	
D12 OCEAN DILUTION	Disqualified (ES&H, Treaty)	
D13 DEEP SPACE LAUNCH	Eliminated (Retrievability, ES&H)	

IMMOBILIZATION WITH RADIONUCLIDES OPTIONS

I1 UNDERGROUND NUCLEAR DETONATION	Disqualified (ES&H, Licensing/Regulatory)	
I2 BOROSILICATE GLASS IMMOBILIZATION (DWPF)	Eliminated (ES&H, Cost)	
I3 BOROSILICATE GLASS IMMOBILIZATION (NEW FACILITY)		Reasonable
I4 CERAMIC IMMOBILIZATION		Reasonable
I5 ELECTROMETALLURGICAL TREATMENT		Reasonable
I6 BOROSILICATE GLASS OXIDATION / DISSOLUTION		Reasonable

REACTOR AND ACCELERATOR OPTIONS

R1 EURATOM MOX FABRICATION / REACTOR BURNING		Reasonable
R2 EXISTING LIGHT WATER REACTORS (LWRS)		Reasonable
R2A PARTIALLY COMPLETED LWRS		Reasonable
R3 EVOLUTIONARY OR ADVANCED LWRS		Reasonable
R4 NAVAL PROPULSION REACTORS	Disqualified (Transparency)	
R5 MODULAR HELIUM REACTORS (MHRS)	Eliminated (Technical Maturity)	
R6 CANDU HEAVY WATER REACTORS		Reasonable
R7 ALMRS WITH PYROPROCESSING	Eliminated (Technical Maturity)	
R8 ACCELERATOR CONVERSION / MOLTEN SALT	Eliminated (Technical Maturity)	
R9 ACCELERATOR CONVERSION / PARTICLE BED	Eliminated (Technical Maturity)	
R10 EXISTING LWRS WITH REPROCESSING	Disqualified (Theft/Diversión, Policy)	
R11 ADVANCED LWRS WITH REPROCESSING	Disqualified (Theft/Diversión, Policy)	
R12 ACCELERATOR-DRIVEN MHRS	Eliminated (Technical Maturity)	
R13 ALMRS WITH RECYCLE	Disqualified (Technical Maturity, Policy)	
R14 PARTICLE BED REACTORS	Eliminated (Technical Maturity)	
R15 MOLTEN SALT REACTORS	Eliminated (Technical Maturity)	

1.7.3 Disposition of Surplus Highly Enriched Uranium

A summary of the results of the screening process for highly enriched uranium disposition is shown in Figure 1-5.

1.7.3.1 HEU Disposition Options Determined to be Reasonable Alternatives for Detailed Study

Four of the nine options were selected as reasonable alternatives for disposition of HEU, in addition to the baseline option of No HEU Disposition Action (continued storage):

- (H-2) Direct Sale of HEU (with buyer to blend to LEU)
- (H-6) Blend to LEU (19% Enrichment) and Sell
- (H-8) Blend to LEU (~5% Enrichment) and Sell
- (H-9) Blend to LEU (19% or less Enrichment) and Discard as Waste¹³

1.7.3.2 HEU Disposition Options Rated but Eliminated in the Screening Process

Four of the nine options were eliminated based on multiple low ratings and/or judgments that they were significantly less desirable than the reasonable alternatives discussed above. The options eliminated would not recover any energy value or near-term monetary value from the HEU. Since HEU has economic value as a fuel for nuclear power plants while plutonium currently does not, no disposal option can be justified for HEU while it can be justified for plutonium. The eliminated options are:

- (H-3) Emplacement of HEU in Deep Boreholes
- (H-4) Immobilization of HEU with High Level Waste
- (H-5) Blend to LEU (19% Enrichment) and Store Indefinitely
- (H-7) Blend to LEU (5% Enrichment) and Store Indefinitely

Figure 1-5. Summary of Screening Results for Highly Enriched Uranium Disposition

HIGHLY ENRICHED URANIUM DISPOSITION OPTIONS

H-1 NO HEU DISPOSITION ACTION		Baseline
H-2 DIRECT SALE OF HEU		Reasonable
H-3 EMPLACEMENT OF HEU IN DEEP BOREHOLES	Eliminated (Timeliness, Cost-Effectiveness)	
H-4 IMMOBILIZATION OF HEU WITH HIGH LEVEL WASTE	Eliminated (Timeliness, Cost-Effectiveness)	
H-5 BLEND TO 19% LEU AND STORE	Eliminated (Cost-Effectiveness)	
H-6 BLEND TO 19% LEU AND SELL		Reasonable
H-7 BLEND TO 5% LEU AND STORE	Eliminated (Cost-Effectiveness)	
H-8 BLEND TO 5% LEU AND SELL		Reasonable
H-9 BLEND TO 19% OR LESS AND DISCARD AS WASTE (HEU WITH NO COMMERCIAL VALUE)		Reasonable

¹³Only for the disposition of HEU determined to have no commercial value. For HEU with commercial value, disposal cannot be justified.

1.7.4 Disposition of Surplus Uranium-233 and Other Minor Actinides

The proposed scope of the overall disposition program included fissile materials that did not result from weapons dismantlement, including uranium-233 and other minor actinides (e.g., Americium). It was determined that there were not sufficient inventories of surplus minor actinides to represent a significant proliferation threat. Therefore the screening evaluations were focused on options for disposition of surplus U-233. A summary of the results of the screening process for U-233 disposition is shown in Figure 1-6.

1.7.4.1 U-233 Disposition Options Determined to be Reasonable Alternatives for Detailed Study

Three of the eight options were selected as reasonable alternatives for disposition of U-233, in addition to the baseline option of No U-233 Disposition Action (continued storage):

- (U-2) Nitrate Blend-Down to ~10% U-233, Storage of Blended Product
- (U-3) Nitrate Blend-Down to ~10% or less U-233, Disposal of Blended Product as Waste
- (U-4) Discard to the Waste Isolation Pilot Plant (WIPP)

1.7.4.2 U-233 Disposition Options Determined to be Unreasonable

Three of the eight options were rated against all criteria, but eliminated based on multiple low ratings and/or judgments that they were significantly less desirable than the reasonable alternatives discussed above. The eliminated options are:

- (U-5) Emplacement of U-233 in Deep Boreholes
- (U-7) Immobilization with High Level Waste and Emplacement in High Level Waste Repository

These options would take significantly more time than blending options and be significantly less cost-effective if done only for U-233 disposition. However, if either of these options are selected for plutonium disposition, there would probably be low incremental costs for using them for U-233 disposition as well. Therefore, the assessment of these options for plutonium disposition will include the possibility that the U-233 inventories are also treated in this manner.

- (U-8) DOE Reactor Irradiation

This option would take significantly more time than blending options and be significantly less cost-effective.

One of the options was disqualified in the screening process due to technical viability considerations:

- (U-6) Discard to Liquid High Level Waste Tanks

This option was disqualified because of criticality concerns associated with putting fissile materials in the waste tanks.

Figure 1-6. Summary of Screening Results for Uranium-233 Disposition

URANIUM-233 DISPOSITION OPTIONS

U-1	NO U-233 DISPOSITION ACTION		Baseline
U-2	BLEND TO ~10% AND STORE		Reasonable
U-3	BLEND TO ~10% OR LESS AND DISCARD AS WASTE		Reasonable
U-4	DISCARD TO WIPP		Reasonable
U-5	DEEP BOREHOLE EMPLACEMENT		Eliminated (Timeliness, Cost-Effectiveness)
U-6	DISCARD TO LIQUID HIGH LEVEL WASTE TANKS	Disqualified (Technical Viability)	
U-7	IMMOBILIZATION WITH HIGH LEVEL WASTE		Eliminated (Timeliness, Cost-Effectiveness)
U-8	DOE REACTOR IRRADIATION		Eliminated (Timeliness, Cost-Effectiveness)

SECTION 2. CRITERIA FOR SCREENING LONG-TERM STORAGE AND DISPOSITION OPTIONS

2.1. INTRODUCTION

Significant quantities of weapons-usable fissile materials (primarily plutonium and highly enriched uranium) have become surplus to national defense needs both in the United States and Russia. These stocks of fissile materials pose significant dangers to national and international security. The dangers exist not only in the potential proliferation of nuclear weapons but also in the potential for environmental, safety and health consequences if surplus fissile materials are not properly managed both in storage and disposition.

Screening criteria were developed to guide the selection of options that best achieve the fissile nuclear material long-term storage and disposition goals of the U.S. Government. The screening criteria incorporate the policy objectives articulated in the President's Nonproliferation and Export Control Policy of September 1993 and the January 1994 "Agreement between the United States and Russia on Nonproliferation of Weapons of Mass Destruction and their Means of Delivery," as well as the analytical framework established by the National Academy of Sciences in their study on disposition of surplus plutonium.

The criteria were developed to reflect the following overall goals developed in the initial strategic planning within the Department of Energy Office of Fissile Material Disposition:

- Consistent with National policy and nonproliferation strategy, develop a national program for management, control, and disposition of all U.S. surplus, weapon-usable fissile nuclear materials which will:
 - Minimize or eliminate the risk that these materials will be reused in weapons.
 - Assure that environmental, safety, and health risks do not exceed acceptable norms.
 - Provide a practical demonstration for other nations' nuclear material disposition programs and provide the technical basis to support negotiations for bilateral or multilateral reductions in surplus fissile material inventories.
 - Be cost effective consistent with meeting strategic objectives and these programmatic goals.
 - Achieve Government and public consensus through stakeholder and public involvement in the program planning and decision process.
- Foster cooperation with Russia and other countries through joint studies to help reach consensus in their implementation of comparable programs to reach similar goals on a comparable schedule.
- Assure that, at the earliest practical date, all U.S. surplus fissile nuclear materials are placed in safe, controlled, inspectable storage.
- Optimize and execute technical plans for disposing of surplus highly enriched uranium, or blending it down to low enriched uranium.
- For weapon-usable plutonium, provide credible options which can be utilized for safe and controlled disposition of approximately 50 MT of these materials.
- Integrate the minor quantities of other surplus fissile material isotopes or byproducts of uranium, plutonium and other fissile actinides into this program.

A preliminary set of criteria was presented to the public and stakeholders through a set of questionnaires and public hearings. Input from questionnaire responses, comments received during meetings and written input to the department were incorporated into the final criteria. More detailed discussion of the public input and the impact this input had on the screening criteria is presented in Appendix A.

Table 2-1 lists the criteria used in the screening evaluations. The order presented is not intended to imply relative importance among the criteria.

Each criterion has two or more factors to be assessed. Table 2-2 lists the criteria and factors for both disposition and storage. The disposition and storage criteria are listed in parallel columns for comparison. While similar, the two sets are not identical because of fundamental differences between actions.

Most criteria have a “potential disqualifier” that was used to identify potentially fatal flaws or weaknesses of an option. For example, an option which would be unlikely to comply with ES&H regulations or which would create wastes for which there is no known or practical disposal technology, capability, or capacity was ruled out from further consideration under the ES&H criterion. Table 2-3 lists the potentially disqualifying factors for each storage and disposition criterion. Options which have one or several of these characteristics were disqualified in the screening process. Following the table are more detailed descriptions of each of the criteria and the factors associated with each criterion.

A substantial amount of discussion in the screening process as well as the public scoping process centered around achieving the “Spent Fuel Standard” proposed by the National Academy of Sciences as an adequate degree of proliferation resistance.¹ To meet the spent fuel standard, options for the disposition of weapons plutonium should seek to make this plutonium roughly as inaccessible or unattractive for weapons use as the much larger and growing quantity of plutonium that exists in spent fuel from commercial reactors. By meeting the spent fuel standard, the proliferation and re-armament threat associated with the surplus plutonium would be no greater than the threat resulting from plutonium in spent fuel, and the surplus plutonium would no longer require a unique level of domestic and international safeguards. Achieving the Spent Fuel Standard relates to the first two disposition criteria.

The Spent Fuel Standard described here consists of three parts. These include the radiological, physical and chemical properties of the material form that make any residual surplus plutonium as inaccessible for recovery as the plutonium in commercial spent fuel. These characteristics directly influence the particular requirements, regulations, and practices for the application of safeguards and security, for both domestic and international purposes, and therefore the material needs to meet all three characteristics in order to satisfy the Spent Fuel Standard.

The characteristics that comprise the spent fuel standard include:

- high radiation dose rate: lethal to unprotected humans, facilitates monitoring of material.
- large & heavy integral assembly: impossible for individual to move without machinery.
- dilute, substantially homogeneous solid matrix: concentrations of less than a few weight percent and dispersed along with other elements to complicate chemical separations.

¹National Academy of Sciences, Committee on International Security and Arms Control, Management and Disposition of Excess Weapons Plutonium, National Academy Press, Washington, DC., 1994.

Table 2-1a. Screening Criteria for Long-Term Storage

1. Resistance to Theft or Diversion by Unauthorized Parties: The site and facility must be capable of providing for comprehensive protection and control of weapons-usable fissile materials (i.e., meet the stored weapons standard).
2. Technical Viability: There should be a high degree of confidence that a facility and site infrastructure can provide storage of nuclear components and materials for at least 50 years.
3. Environmental, Safety & Health Compliance: High standards of public and worker health and safety, and environmental protection must be met, and significant additional ES&H burdens should not be created.
4. Cost Effectiveness: Long-term storage should be accomplished in a cost-effective manner and be compatible with reasonable disposition alternatives.
5. Timeliness: Long-term storage should be implemented in a timely manner.
6. Fosters Progress and Cooperation with Russia and Other Countries: A facility must accommodate international inspections and must establish appropriate standards for storage and protection of international nuclear material inventories.
7. Public and Institutional Acceptance: An alternative should be able to muster a broad and sustainable consensus on the manner in which long-term storage is accomplished.

Table 2-1b. Screening Criteria for Disposition

1. Resistance to Theft or Diversion by Unauthorized Parties: Each step in the disposition process must be capable of providing for comprehensive protection and control of weapons-usable fissile material.
2. Resistance to Retrieval, Extraction, and Reuse by Host Nation: The surplus material must be made highly resistant to potential reuse in weapons to reduce reliance on institutional controls and demonstrate that the arms reductions will not be easily reversed.
3. Technical Viability: There should be a high degree of confidence that the alternative will be technically successful.
4. Environmental, Safety & Health Compliance: High standards of public and worker health and safety, and environmental protection must be met, and significant additional ES&H burdens should not be created.
5. Cost Effectiveness: Disposition should be accomplished in a cost-effective manner.
6. Timeliness: There is an urgent need to minimize the time period that surplus fissile materials remain in weapons-usable form.
7. Fosters Progress and Cooperation with Russia and Other Countries: The alternative must establish appropriate standards for the disposition of surplus weapons-usable fissile material inventories, support negotiations for bilateral or multilateral reductions in these materials, and each step in the disposition process must allow international inspections.
8. Public and Institutional Acceptance: An alternative should be able to muster a broad and sustainable consensus on the manner in which disposition is accomplished.
9. Additional Benefits: The ability to leverage government investments for disposition of surplus materials to contribute to other national or international initiatives should be considered.

TABLE 2-2. - Criteria and Factors

Disposition Criteria and Factors	Long-Term Storage Criteria and Factors
Resistance to Theft or Diversion by Unauthorized Parties Low Inherent Attractiveness Minimization of Transportation & Sites Safeguards and Security Assurance	Resistance to Theft or Diversion by Unauthorized Parties Safeguards and Security Assurance Minimization of Transportation & Sites
Resistance to Retrieval, Extraction and Reuse by Host Nation Difficulty of Retrieval, Extraction and Reuse Assurance of Detection of Retrieval & Extraction	not used
Technical Viability Technical Maturity Capacity/capabilities of Facilities/Infrastructure Regulatory/ Licensing Requirements	Technical Viability Condition and Reliability of Facilities/Infrastructure Capacity/capabilities of Facilities/Infrastructure Regulatory/ Licensing Requirements
Environment, Safety, and Health Public & Worker Health and Safety Waste Minimization Known and Manageable Waste Forms Environment and Resource Conservation	Environment, Safety, and Health Public & Worker Health and Safety Environment and Resource Conservation
Cost Effectiveness Life Cycle Cost Investment and Start-up Costs Potential for Cost Sharing Cost Estimate Certainty	Cost Effectiveness Life Cycle Cost Investment and Start-up and Transition Costs Utilization of Existing Infrastructure Cost Estimate Certainty
Timeliness Time to Start Disposition Time to Complete Disposition Schedule Certainty	Timeliness Time to Open Facility Time to Complete Transition Schedule Certainty
Fosters Progress and Cooperation with Russia and Other Countries Appropriateness as International Standard Leverage Provided in International Negotiations Transparency	Fosters Progress and Cooperation with Russia and Other Countries Appropriateness as International Standard Transparency
Public & Institutional Acceptance Ability to Create a Sustainable Consensus Socioeconomic Impacts Adherence to Treaties, Policies and Statutes	Public & Institutional Acceptance Ability to Create a Sustainable Consensus Adherence to Other Policies and Statutes Socioeconomic Impacts
Additional Benefits Contributes to National Initiatives Contributes to International Initiatives Potential Technology Spin-offs	not used

TABLE 2-3. Potential Disqualifiers or Fatal Flaws

Long-Term Storage Criteria	Potential Disqualifiers or Fatal Flaws
Resistance to Theft or Diversion by Unauthorized Parties:	Option will not be considered if the risk of theft or diversion during transportation or long-term storage is greater than those involved in the process of dismantlement and storage of weapons components ("Stored Weapons Standard").
Technical Viability:	Facility & infrastructure not likely to be viable for a ~ 50 year storage period.
Environment, Safety, and Health:	Compliance with ES&H regulations is unlikely; close to densely populated area; or inadequate buffer area.
Cost Effectiveness:	Life cycle costs are greater than use of current facilities with no significant advantages in other criteria.
Timeliness:	Facility can not be available to accept storage containers within 10 years (2005).
Fosters Progress and Cooperation with Russia and Other Countries:	Cannot be monitored or confirmed by international inspections.
Public and Institutional Acceptance:	Violations of national policies or statutes which are not likely to be changed.

Disposition Criteria	Potential Disqualifiers or Fatal Flaws
Resistance to Theft or Diversion by Unauthorized Parties:	Unable to meet the "Stored Weapons Standard" during processing or storage, or proliferation resistance of the "Spent Fuel Standard" at disposition.
Resistance to Retrieval, Extraction and Reuse by Host Nation:	Risk of retrieval, extraction or reuse after disposition is no better than long-term storage.
Technical Viability:	<ul style="list-style-type: none"> • No assurance of demonstrating technical feasibility in time for the option to be considered in the decision process. • Key technology concept not likely to be demonstrated on a reasonable scale in a timely fashion. • Capacities or capabilities of facilities or infrastructure are insufficient to accommodate the disposition mission within constraints not likely to be changed. • Regulatory and licensing requirements are regarded as very uncertain and unlikely to be resolved in a timely fashion.
Environment, Safety, and Health:	<ul style="list-style-type: none"> • Unacceptably high probability of severe accident. • Compliance with ES&H regulations is unlikely. • Wastes are created for which there is no known or practical disposal technology, capability or projected repository capacity.
Cost Effectiveness:	<ul style="list-style-type: none"> • Life cycle or start-up and investment costs, whichever are the more significant, are an order of magnitude greater than the average of those costs for other similarly desirable, but less expensive options. • There is no rational basis for estimating the costs of the option and it is impractical to develop one.
Timeliness:	<ul style="list-style-type: none"> • Disposition could not begin within about a decade. • Overall disposition program would not be completed (all material meets spent fuel standard) within ~30 years after initiation. • No rational, substantive basis exists or can be developed for evaluating the schedule.
Fosters Progress and Cooperation with Russia and Other Countries :	• Neither the process nor the final condition is amenable to transparent confirmation by international inspections.
Public and Institutional Acceptance:	• Violations of national policies, international treaties, or statutes which are not likely to be changed.
Additional Benefits:	none

The nuclear properties of the plutonium (isotopic composition) have only a secondary effect on proliferation resistance. There is a concern for potential theft or diversion of non-weapon-grade plutonium by unauthorized parties because these materials can be used in a nuclear explosive device. However, isotopic qualities can make the material less attractive for U.S. and Russia to reuse, because both countries have based their entire technology and infrastructure on the use of weapons-grade plutonium. Inability to test new designs, as would result from a Comprehensive Test Ban Treaty, would make the use of reactor-grade plutonium by these countries even less likely.

The National Academy of Sciences recognized that the radiation barrier associated with spent fuel will eventually decay and that long-term steps to reduce the proliferation risks associated with the entire global stock of plutonium will be needed. The Nuclear Waste Policy Act, as amended establishes the path forward for ultimate disposal of spent fuel in a mined geologic repository, where geologic barriers reduce the proliferation risks beyond the time period of decay for the radiation barrier.

As a result of the screening process, the concept of the Spent Fuel Standard as an appropriate degree of proliferation resistance was re-affirmed. This was a result of evaluating options against the full set of criteria and concluding that the additional degree of proliferation resistance provided by technologies that go beyond the spent fuel standard is not worth the substantial additional time and cost required. In light of the significant quantities of plutonium that are already contained in spent fuel and the path forward for ultimate disposition of those forms meeting the spent fuel standard established by the Nuclear Waste Policy Act, the spent fuel standard is considered adequate.

2.2. CRITERIA DESCRIPTIONS

Criterion 1. Resistance to Theft or Diversion by Unauthorized Parties (Applies to both Disposition and Long-Term Storage)

This first criterion was used to address the risk of theft of weapon-usable nuclear material primarily during transportation, storage, and processing, as well as the risk of theft after disposition is completed. The threat was presumed to be primarily theft by terrorists, sub-national groups or aspiring nuclear states, in addition to potential theft by disgruntled employees. In general, this threat can be reduced by minimizing the handling and processing of the material and applying effective Safeguards and Security (S&S) measures. Important characteristics included the inherent attractiveness of the weapons-usable material, the number of transportation steps and sites involved, and the number and characteristics of the processing steps that influence the effectiveness of standard safeguards and security practices. The transportation, storage and processing must meet the Stored Weapons Standard² and the condition after disposition must meet or exceed the proliferation resistance of the Spent Fuel Standard.³

Factors considered when applying this criterion were:

- a) Low Inherent Attractiveness: This factor favored disposition or storage options that minimize the attractiveness of the physical, chemical, or isotopic makeup of the nuclear material during processing, transportation or storage. The risk of theft (or weapon use) is reduced if material is only available in small quantities and/or is in a physical and chemical form or matrix that makes recovery difficult.
- b) Minimization of Transportation & Sites: The more complex the logistics, the more opportunities there are for theft. Disposal scenarios that involve very complex logistics with many transfers and storage locations, with attendant transportation requirements, were considered to be more vulnerable to theft.
- c) Safeguards and Security Assurance: The effectiveness of the S&S protection depends on the form of the fissile material and the characteristics of the processes and facilities involved in the storage and disposition activities.

Criterion 2. Resistance to Retrieval, Extraction and Reuse by the Host Nation (Applies to Disposition only)

The goal is to make it unlikely that the surplus weapons-usable materials will ever be used in weapons. High resistance to retrieval would provide confidence to other nations that a relatively large resource expenditure (cost and time) would be required to reconstruct the stockpile from disposed material. Barriers to reuse result from the form of the material,

² The Stored Weapons Standard was defined by the National Academy of Sciences to mean that, to the extent possible, the high standards of security and accounting applied to the storage of intact nuclear weapons should be maintained for these materials throughout dismantlement, storage and disposition.

³ The Spent Fuel Standard was defined by the National Academy of Sciences to mean that options for the disposition of plutonium should seek to make this plutonium roughly as inaccessible or unattractive for weapons use as the much larger and growing stock of plutonium in civilian spent fuel.

physical location of the material, and institutional controls (such as IAEA Safeguards). A goal of disposition is to reduce reliance on institutional controls.

Modification of the weapons-usable material to make it as difficult to use for weapons production as plutonium contained in spent commercial reactor fuel would make the proliferation and re-armament threat associated with the surplus weapons-usable materials no greater than the threat resulting from plutonium in spent fuel, and the surplus weapons-usable materials would no longer require a unique level of domestic and international safeguards. From the perspective of this criterion alone, it might seem to be even better to make the weapons-usable material as difficult to use as mining and enriching natural uranium. However, the greater degree of proliferation resistance provided by technologies that go beyond the spent fuel standard were not considered to be worth the substantial additional time and cost required, especially in light of the significant quantities of plutonium that are already contained in spent fuel.

For HEU and U-233, this criterion can be readily met by blending the fissile material with depleted, natural or low-enriched uranium to make the material unusable in weapons.

For the specific issues to be addressed in ongoing evaluations, the "Host Nation" is the United States for most of the options considered. However, the motivation for taking these actions are driven by concerns about how well Russia can safeguard its material. How our actions would foster progress and cooperation with Russia to provide effective storage and disposition of their materials is addressed in Criterion 7 discussed below.

Factors considered when applying this criterion were:

- a) Difficulty of retrieval, extraction and reuse (disposition only): This factor considered the difficulty (reflected by cost and time) of retrieval of surplus weapons-usable material and its reuse in weapons.
- b) Assurance of detection of retrieval and extraction (disposition only): This factor primarily dealt with how difficult the material would be to retrieve and extract in a clandestine manner, which depends on the resultant material location and form.

Criterion 3. Technical Viability (Applies to both Disposition and Long-Term Storage)

There should be a high degree of confidence that an alternative will be technically successful. It is therefore of interest to rely on technologies that have been proven for similar applications and have a high likelihood of success. New technologies (or new applications of old technologies) may also require an extended period for licensing or regulatory approval due to the immaturity of the process or regulatory framework. In the case of long-term storage, the viability of proposed facilities was assessed. This included the state, readiness and projected lifetime of facilities and infrastructure and the processing/storage/disposal capacity of the facilities.

- a) Technical maturity (applies to disposition options only): Near term actions require mature and proven processes. Technologies that are less mature would require a number of years to prove themselves and impose risks that they will not meet technical goals, be adequately mature for deployment, or be more costly and take more time than projected.
- b) Condition and Reliability of Facilities and Infrastructure (applies to long-term storage options only): Initiation of new processing and storage activities in existing DOE facilities will likely require upgrades. Most of the processing capability necessary to support long-term storage in the nuclear weapons complex is either in standby status or inoperative. This

factor assesses the readiness of existing facilities to support the various storage options under consideration, and how likely it is that these facilities would remain viable for the duration of the long-term storage period of at least 50 years.

- c) Capacity/capabilities of Facilities and Infrastructure (applies to both disposition and long-term storage): The capacity and capabilities of facilities that would be employed by an option was considered. This applies to both processing facilities that convert material into a form suitable for long-term storage or disposition, as well as the capacity of above or below ground repositories and/or waste repositories.
- d) Regulatory/licensing requirements (applies to both disposition and long-term storage options): New facilities or the use of new technologies may be more difficult to license or certify for operation. In some cases, this may be site dependent since state and local, as well as Federal regulations will almost certainly apply. It was recognized that legislation, regulations, and permitting requirements are constantly evolving. This introduced an element of project risk that was considered in weighing an option.

Criterion 4. Environment, Safety and Health (Applies to both Disposition and Long-Term Storage)

The goal is to select options which would provide safe and healthy conditions for workers and the public and provide as little environmental impact as possible.

- a) Public and worker health and safety (both long-term storage and disposition): This factor considered the risk of public and worker exposure to radiation and hazardous materials during transportation, storage, processing and final disposition. Exposure to workers and the public under normal operating conditions and in the event of an accident were considered.
- b) Waste minimization (disposition only): This factor considered the potential impact of the waste created by the disposition option including transportation, storage, processing and final disposition. It assessed the long-term, irreversible consequences of the disposition which are not captured by cost.
- c) Known and manageable waste forms (disposition only): This factor considered the ability to deal with the waste created by the disposition option. It would screen out options which create waste for which there is no known or likely practical treatment or disposal capability, because the technical viability or costs of dealing with these wastes cannot be readily estimated.
- d) Environment and resource conservation (both long-term storage and disposition): This factor considered the overall environmental impact of the storage or disposition option, including use of scarce resources, which is not captured by cost.

Criterion 5. Cost Effectiveness (Applies to both Disposition and Long-Term Storage)

A goal of the program is to minimize the incremental cost impact on the Government and taxpayers. Although the national security benefits clearly outweigh the costs involved, significant budget pressures are projected throughout program execution. Timing, allocation, and uncertainties of costs were assessed. The following cost-related performance factors were considered to evaluate the extent to which a particular option is cost effective.

- a) Life cycle cost (disposition and long-term storage): Life cycle cost is defined as the net present value of all incremental cash flows. Life cycle cost includes adjustments for revenues that may be produced by electric power production but does not include the sunk costs of existing facilities or other costs that would be incurred whether or not any action is taken.
- b) Investment and start up cost (disposition and long-term storage): Investment and start up cost refers to research and development, construction, retrofit, and program infrastructure costs that are incurred early in the program.
- c) Potential for cost sharing (disposition): The potential for cost sharing refers to the willingness of other government agencies or private industry to partially fund the disposition effort. Some disposition options may provide benefits to these organizations such as demonstration of a new technology or production of a useful product. These organizations may be willing to provide some funding, potentially reducing overall costs to the government.
- d) Utilization of existing infrastructure (long-term storage): Utilization of existing infrastructure refers to the use of existing storage facilities with associated infrastructure (e.g., safeguards and security and analytical support for long-term storage). This use might affect the cost, environmental, or socioeconomic impacts of fissile material storage.
- e) Cost estimate certainty (disposition and long-term storage): Cost estimate certainty refers to the level of confidence regarding the forecast cost of an option and the actual cost that would be incurred if the option is selected. Cost estimates must be based upon assumptions and approximations and may be in error. Cost estimate certainty was lower for those technology options that are in the research or development stage and higher for mature technologies or existing facilities.

Criterion 6. Timeliness (Applies to both Disposition and Long-Term Storage)

A goal of the program is to act in a timely manner for long-term storage and in an urgent manner for disposition. This reduces the risks of theft or diversion of weapons-usable material and would send a positive signal to Russia and to the international community regarding disarmament. There is a real risk in delaying actions for any substantial period of time. The following schedule-related factors were developed to evaluate the extent to which a particular option is timely.

- a) Time to start disposition/Time to open facility (disposition and long-term storage): The time required to start disposition or open a facility for long-term storage is one measure of timeliness. Options that show progress sooner were preferred.
- b) Time to complete disposition/Time to complete transition to long-term storage (disposition and long-term storage): The time required to complete disposition or to complete placement of plutonium in a long-term storage facility is another measure of timeliness. Options that would complete disposition or storage transition sooner were preferred. For options that achieve a proliferation-resistant waste form (e.g. spent fuel, immobilization with radionuclides) which is ultimately slated for a high-level waste repository, the "time to complete" is the time to achieve the proliferation-resistant waste form, which would be stored pending repository disposal.
- c) Schedule certainty (disposition and long-term storage): Schedule certainty refers to the level of confidence regarding the forecast schedule of an option and the actual schedule

that would be realized if the option was selected. Schedule estimates must be based upon assumptions and approximations and may be in error. Schedule certainty was lower for those technology options that are in the research or development stage and higher for mature technologies and/or existing facilities.

Criterion 7. Fosters Progress and Cooperation with Russia and Other Countries (Applies to both Disposition and Long-Term Storage)

In view of the current political and economic instability in Russia, it is essential that long-term storage and disposition activities in the U.S. set appropriate standards and promote timely implementation of secure monitoring regimes and ultimate disposition of nuclear materials in Russia and other countries. An important element of the U.S. disposition program is to work jointly with the Russians to study issues and develop solutions that are appropriate for each country. Agreements for secure, safeguarded management and disposition of fissile materials from dismantled nuclear weapons could also help make clear that the nuclear powers are fulfilling their disarmament obligations under Article VI of the Non-Proliferation Treaty.

The factors listed below identify the features of storage or disposition options that were considered to lead to a more secure status of weapon-usable nuclear material in other countries.

- a) **Appropriateness as International Standard** (both long-term storage and disposition): A goal is to implement disposition and long-term storage standards that are jointly developed to achieve similar results in Russia or other countries. Therefore, analysis of options must consider their adequacy if applied by other countries. This requires assessments of threat scenarios in other countries, and of how various storage or disposition options would perform under these scenarios. For a standard to be appropriate, a commensurately low risk of the material being used in weapons (either by the host nation or any other group) must be achieved.
- b) **Leverage Provided for International Negotiations** (both long-term storage and disposition): A goal of the program is to provide the technical basis for negotiating bilateral or multilateral reductions in inventories of weapons usable fissile materials. This requires consideration of the technical, economic and policy contexts associated with implementation of options in Russia or other countries.
- c) **Transparency** (both long-term storage and disposition): It is desirable that long-term storage and disposition activities in the US, Russia, and other declared nuclear states be observable by IAEA and signatories to the Non Proliferation Treaty and provide assurances that weapons stockpiles of nuclear states are being reduced. Assessments were based on the availability of procedures and technologies for observing fissile material processing and material accounting systems. Consideration of the difficulty to reverse the disposition process in a clandestine fashion are captured in Criterion 2.

Criterion 8. Public and institutional acceptance (Applies to both Disposition and Long-Term Storage)

A goal of the program is to select alternatives that are acceptable to the public and cognizant government agencies. It is anticipated that each option will incur some amount of opposition from various governmental agencies, public interest groups, or individuals. An option that is generally acceptable is preferred.

- a) Ability to create a sustainable consensus (disposition and long-term storage): This factor considered the ability to generate and maintain a broad constituency for a particular option. This is important since changes in governmental bodies will occur throughout the implementation time period. Public dissemination of pertinent information explaining the reasoning behind decisions contribute to creating a sustainable consensus.
- b) Socioeconomic impacts (disposition and long-term storage): Positive socioeconomic impacts include an increase in the tax base for local governments or employment base for citizens where facilities are being constructed or staffed. Negative socioeconomic impacts include disruption of a local community due to increased traffic, denial of land use for other purposes, and the boom-bust economic cycle associated with construction or site abandonment.
- c) Policy/statute compatibility (disposition and long-term storage): One measure of the potential for gaining approval is the degree to which selection of an option is compatible with existing policies and statutes. The need for significant legislative or regulatory changes may imply an incompatibility with current public and institutional interests.

Criterion 9. Additional Benefits (Applies to Disposition only)

A number of the options proposed for disposition may have potential benefits to the Government, the commercial sector, and the public in general. These potential additional benefits were considered when evaluating options as a positive factor. However, a lack of additional benefits was not a negative factor.

- a) Contributes to National Initiatives (disposition only): Some options could benefit other government missions through the sharing of costs and other burdens with other Department of Energy or Department of Defense missions or with other government agencies. For example, medical isotopes can be produced as a byproduct of fissile material burning and immobilization options may benefit waste management programs.
- b) Contributes to International Initiatives (disposition only): Some options could benefit other international initiatives through the sharing of costs and other burdens with other government agencies.
- c) Potential Technology Spin-offs (disposition only): Options that develop new technologies or intellectual property that can be shared with, or will benefit the U.S. commercial sector provide additional benefits to the disposition program.

SECTION 3. OPTIONS CONSIDERED IN THE SCREENING PROCESS

A list of possible options was developed and prepared in a format to facilitate the screening process. The approach considered various physical and chemical forms of material, defined potential final locations and conditions, and specified major interim operations technically necessary to transfer the materials into each of the final locations and conditions. National Laboratory and DOE reviews expanded and refined the list of options that were considered in the screening process. Additional options were brought to the attention of the DOE through the Public Scoping Workshops held from August through October 1994.

3.1 DETERMINATION OF LONG-TERM STORAGE OPTIONS

The starting point for defining long-term storage options was the set of alternatives considered for nuclear material storage in the Nuclear Weapons Complex Reconfiguration Program. These were augmented by options suggested by the public during the PEIS scoping process. (It should be noted that one or more alternatives eventually selected for long-term storage will become the "No Action" alternative for disposition.)

A total of 5 long-term storage options were evaluated in the screening process to determine those that should be considered reasonable alternatives for further evaluation in the Programmatic Environmental Impact Statement (PEIS), and in a detailed technical, economic, and non-proliferation evaluation process. These five options are broad in character, but represent a complete set of options for long-term storage. There are numerous variations within these broad options, reflecting different sites that could be employed for the long-term storage mission.

The options considered for long-term storage in the screening process were:

- (LTS-1) The No Action Alternative which would leave the weapons-usable materials in the storage facilities utilized for safe, secure interim storage.
- (LTS-2) Upgrade of interim storage facilities to make them suitable for long-term storage and allow for partial consolidation of inventories at certain sites. Examples of existing sites where plutonium could continue to be stored and facilities could be upgraded include Idaho National Engineering Laboratory, Oak Ridge, Pantex, Savannah River, and Hanford.
- (LTS-3) Consolidation of the weapons-usable fissile materials at one of several DOE sites (e.g., Savannah River Site, Pantex, Oak Ridge, Idaho, Hanford and the Nevada Test Site).
- (LTS-4) Utilization of potentially suitable existing facilities at non-Department-of-Energy domestic sites.
- (LTS-5) Utilization of potentially suitable non-domestic sites for long-term storage.

There were several options proposed by the public during the Scoping Workshops and contained in written comments submitted during the public comment period that are captured in the fourth broad option, including the suggestion that Department of Defense facilities be

considered. There were also a number of options proposed that would utilize locations outside the United States that are captured in option LTS-5.

3.2 DETERMINATION OF SURPLUS PLUTONIUM DISPOSITION OPTIONS

The National Academy of Science (NAS) published a study which discusses both the desirability of the disposition of excess Special Nuclear Materials (SNM) and considers various possible options for the disposition of this excess material.¹ This study was used to provide an initial list of plutonium disposition options and as a resource of information for evaluating those options. Also, a number of technology options earlier considered by the DOE Office of Civilian Radioactive Waste Management² and various technology options under development at the DOE weapons laboratories were considered. In addition, options were brought to the attention of the DOE through the Public Scoping Workshops held from August through October 1994.

The disposition of surplus Pu is more than just managing the Pu recovered from nuclear weapons: it includes all of the surplus DOE-owned Pu which is available and suitable for the manufacture of nuclear weapons. Processing and disposal requirements can vary substantially for the different material forms and composition. To facilitate the DOE screening process, a standardized format was prepared to describe and characterize possible options to describe the end-to-end process and final disposition locations, rather than just describing principal technologies.

The approach used in developing a list of potentially viable options consisted of three phases: 1) determination of the surplus Pu inventories by material type or chemical and metallurgical form which must be dispositioned, 2) identification of final ultimate disposition forms and ultimate disposition locations, and 3) determination of necessary processing options which are required or may be desirable to process starting inventories into a given form and location.

3.2.1. Plutonium Available for Disposition

In the course of DOE operations over the past 50 years, on the order of 100 MT of Pu were created and processed, of which approximately 50 MT are anticipated as being surplus and available for disposition, although it is possible that additional Pu will become surplus in the future. Due to the manufacturing operations, reactor operations, and chemical processing which were undertaken during this time, significant quantities of Pu were converted to various chemical, metallurgical, and physical forms. These inventories have been sorted into five major categories (shown in Table 3-1), each of which has unique processing and storage requirements and may require different disposition processing options. Within these five classes, there is a range of materials that may involve different processing, storage and disposition requirements.

¹National Academy of Sciences, Committee on International Security and Arms Control, Management and Disposition of Excess Weapons Plutonium, National Academy Press, Washington, DC., 1994.

²U.S. Department of Energy, DOE/EIS-0046F, "Management of Commercially Generated Radioactive Waste," October, 1980.

Table 3-1. Plutonium Chemical and Physical Forms Likely to be Declared Surplus and Available for Disposition

Surplus Pu pits
Surplus clean metal or oxide
"Rich" Pu residues
"Lean" Pu residues
Unirradiated or only slightly irradiated Pu fuel and targets

The quantity of Pu in pits is expected to constitute about half of the total Pu quantity available for disposition. The metals and oxides are those which could be directly manufactured into nuclear weapons. The rich residues refer to processing and manufacturing residues with relatively high (25% - 85% by weight) Pu concentrations which can be processed using known Pu chemistry operations to recover a high percentage of Pu for weapons use with a low to moderate effort.

The lean residues (plutonium-contaminated leaded-rubber gloves and filters, for example) represents a significant inventory of Pu tied up in chemical or physical forms which will generally require substantially greater effort for chemical recovery prior to weapons use than rich residues. Plutonium in this category is considered more resistant to theft or diversion, and less likely to be used to reconstitute a nuclear arsenal, than rich residues.

The final category primarily involves various alloys of DOE-owned fuel grade Pu in reactor fuel form and plutonium in targets that have not been irradiated in a reactor (or are only slightly irradiated). Since such Pu is readily recoverable from these fuel or target form, disposition will be required.

3.2.2. Plutonium Disposition Options

Using the identification of likely source forms and ultimate disposal site options, required steps for processing, storage, denaturing (if any), and final processing for ultimate disposition were identified. The ultimate disposal sites identified include underground cavities at the Nevada Test Site, U.S. or foreign high level waste repositories, deep boreholes, space, ocean, underground rock and magma formations, and salt caverns (such as the Waste Isolation Pilot Plant in New Mexico).

In general, sufficient processing was added such that all chemical and physical forms can be dispositioned at all ultimate disposition sites. Any complete option description would then consist of a set of at least one pathway to final disposition for each of the chemical and physical forms. This would not preclude later combining options for disposition of the various chemical and physical forms to optimize the overall disposition strategy.

Based on this analysis, the following storage, direct disposal, immobilization, and reactor options were identified:

Storage Options

- (S-1) No Plutonium Disposition Action (Continued Storage)
- (S-2) Radiation Barrier Alloy (Storage with Enhanced Passive Security)

Disposal Options

- (D-1) Direct Emplacement in HLW Repository
- (D-2) Emplacement in Deep Boreholes after Immobilization (without radionuclides)
- (D-3) Direct Emplacement in Deep Boreholes
- (D-4) Discard to the Waste Isolation Pilot Plant
- (D-5) Hydraulic Fracturing into Underground Shale Formations
- (D-6) Injection of Slurry into Deep Underground Wells
- (D-7) Injection into Continental Magma
- (D-8) Melting in Crystalline Rock
- (D-9) Disposal under Ice Caps
- (D-10) Seabed Disposal (Placement on Ocean Floor)
- (D-11) Sub-seabed Emplacement
- (D-12) Controlled Dilution in Oceans
- (D-13) Deep Space Launch

Immobilization with Radionuclides (with Ultimate Geologic Disposal)

- (I-1) Underground Nuclear Detonation
- (I-2) Immobilization in Borosilicate Glass (using Modified DWPF)
- (I-3) Immobilization in Borosilicate Glass (using New Facility)
- (I-4) Immobilization in Ceramics
- (I-5) Electrometallurgical Treatment
- (I-6) Glass Material Oxidation / Dissolution System (GMODS)

Reactor Options (with Ultimate Disposal in High Level Waste Repository)

- (R-1) Euratom Commercial MOX Fabrication / Reactor Burning
- (R-2) Existing U.S. Light Water Reactors (LWRs)
- (R-2A) Partially Completed LWRs
- (R-3) Evolutionary or Advanced LWRs
- (R-4) Naval Propulsion Reactors
- (R-5) Modular Helium Reactors (MHRs)
- (R-6) CANDU Heavy Water Reactors
- (R-7) Advanced Liquid Metal Reactors (ALMRs) with Pyroprocessing (one cycle)
- (R-8) Accelerator-Based Conversion / Molten Salt Target
- (R-9) Accelerator-Based Conversion / Particle Bed Target
- (R-10) Existing LWRs with Reprocessing
- (R-11) Evolutionary or Advanced LWRs with Reprocessing
- (R-12) Accelerator-Driven MHRs
- (R-13) ALMRs with Recycle
- (R-14) Particle Bed Reactors
- (R-15) Molten Salt Reactors

A spreadsheet listing the options is shown in Appendix B, which identifies the steps for the various chemical and physical forms. Appendix B also indicates which of the options were considered in the NAS study or were identified specifically in the Notice of Intent.

3.3 DETERMINATION OF SURPLUS HIGHLY ENRICHED URANIUM DISPOSITION OPTIONS

While many of the same options evaluated for plutonium could have also been evaluated for HEU disposition, a more limited number of options were considered because the options disqualified or eliminated for plutonium disposition were viewed as also being unreasonable for disposition of highly enriched uranium.

Two factors significantly impact the disposition of surplus highly enriched uranium, and result in options that were not available for disposition of other weapons-usable materials:

- The highly enriched uranium can be rendered non-weapons-usable by isotopic dilution to low enriched uranium.
- There is a substantial domestic market for low enriched uranium, which provides opportunities for net revenues to the U.S. Treasury through sale of the highly enriched uranium or the blended low-enriched uranium product that meets specifications for the commercial nuclear fuel market.

A total of 9 disposition options for highly enriched uranium were evaluated to determine those considered reasonable alternatives for further evaluation in the Programmatic Environmental Impact Statement (PEIS), and in a detailed technical, economic, and non-proliferation evaluation process. The options for major federal actions in the disposition of surplus highly-enriched uranium considered in the screening evaluations include the following:

(H-1)	No HEU Disposition Action (Continued Storage)
(H-2)	Direct Sale of HEU (with buyer to blend to LEU)
(H-3)	Emplacement of HEU in Deep Boreholes
(H-4)	Vitrification of HEU with High Level Waste
(H-5)	Blend to LEU (19% Enrichment) and Store Indefinitely
(H-6)	Blend to LEU (19% Enrichment) and Sell the LEU
(H-7)	Blend to LEU (~5% Enrichment) and Store Indefinitely
(H-8)	Blend to LEU (~5% Enrichment) and Sell the LEU
(H-9)	Blend to LEU (19% or less Enrichment) and Discard as Waste

3.4 DETERMINATION OF SURPLUS URANIUM-233 AND OTHER MINOR ACTINIDE DISPOSITION OPTIONS

The proposed scope of the overall disposition program included fissile materials that did not result from weapons dismantlement, including uranium-233 and other minor actinides (e.g., americium). It was determined that there were not sufficient inventories of surplus minor actinides to represent a significant proliferation threat. Therefore the screening evaluations were focused on options for disposition of surplus U-233.

While many of the options evaluated for plutonium disposition could have also been evaluated for U-233 disposition, a more limited number of options were considered because many of the options disqualified or eliminated for plutonium disposition were viewed as also being unreasonable for disposition of U-233.

Three factors significantly impact the options available disposition of U-233:

- Uranium-233 can be isotopically diluted with uranium-238 to ~10% or less U-233 to render it unusable in weapons.
- There is no commercial use of significant quantities of U-233 in either concentrated or isotopically diluted form.
- Several of the plutonium disposition options may also be able to accommodate the U-233 inventories.

A total of 8 disposition options for U-233 were evaluated to determine those considered reasonable for further evaluation in the Programmatic Environmental Impact Statement (PEIS) and in a detailed technical, economic, and non-proliferation evaluation process. The options considered in the screening process included the following:

- (U-1) No U-233 Disposition Action (Continued Storage)
- (U-2) Nitrate Blend-Down to ~10% U-233, Storage of Blended Product
- (U-3) Nitrate Blend-Down to ~10% or less U-233, Disposal of Blended Product as Waste
- (U-4) Discard to the Waste Isolation Pilot Plant (WIPP)
- (U-5) Emplacement of U-233 in Deep Boreholes
- (U-6) Discard to Liquid High Level Waste Tanks
- (U-7) Immobilization with High Level Waste and Emplacement in High Level Waste Repository
- (U-8) DOE Reactor Irradiation

SECTION 4. SUMMARY OF RESULTS

4.1 SCREENING OF LONG-TERM STORAGE OPTIONS

4.1.1. Introduction

A total of five options for long-term storage of national security inventories and programmatic inventories, and surplus materials that are not able to go directly from interim storage to disposition were evaluated to determine those considered reasonable alternatives for further evaluation in the Programmatic Environmental Impact Statement (PEIS), and in a detailed technical, economic, and non-proliferation evaluation process. These five options are broad in character but represent a complete set of options for long-term storage. There are numerous variations within these broad options, reflecting different sites that could be employed for the long-term storage mission.

The options considered for long-term storage in the screening process were:

- (LTS-1) The No Action Alternative which would leave the weapons-usable materials in the storage facilities utilized for safe, secure interim storage.
- (LTS-2) Upgrade of interim storage facilities to make them suitable for long-term storage and allow for consolidation of inventories at certain sites. Examples of existing sites where plutonium could continue to be stored and facilities could be upgraded include Idaho National Engineering Laboratory, Oak Ridge, Pantex, Savannah River, and Hanford.
- (LTS-3) Consolidation of the weapons-usable fissile materials at one of several DOE sites (e.g., Savannah River Site, Pantex, Oak Ridge, Idaho, Hanford and the Nevada Test Site). Major new construction would be involved in this option.
- (LTS-4) Utilization of potentially suitable existing facilities at non-Department-of-Energy domestic sites. Major new construction would be involved in this option.
- (LTS-5) Utilization of non-domestic sites for long-term storage. Major new construction would be involved in this option.

There were several options proposed by the public during the Scoping Workshops and contained in written comments submitted during the public comment period that were considered within the fourth broad option, and also a number of options proposed that would utilize locations outside the United States, that were considered within option LTS-5.

Figure 4-1 is a summary chart showing the relative ratings among the options (except the one disqualified) versus the seven long-term storage screening criteria. The following sections summarize the screening evaluation results. No specific site selections are made or implied in these results.

4.1.2. Baseline Alternative for Long-Term Storage

(LTS-1) No Action (Leave Materials in Safe, Secure Interim Storage)

This option is considered a base case for long-term storage actions using adequate, proven safeguards and security for protection of nuclear materials in interim storage. Other long-term storage options would have some more positive action in terms of upgrading facilities at existing sites or consolidating storage at a new or modified facility(ies). Principal advantages of this option include low cost and short implementation time, both of which are most significant if a disposition strategy is selected which can be implemented in a timely manner to minimize the long-term storage requirements. Principal disadvantages include uncertainties in the long-term viability of the interim storage facilities.

Figure 4-1. Relative Ratings among Long-Term Storage Options

<div style="border: 1px solid black; padding: 10px; display: inline-block; width: 250px;"> <p>LEGEND</p> <p>Relative Ratings among Long Term Storage Options:</p> <p>+ HIGH</p> <p>o MEDIUM</p> <p>— LOW</p> </div>								
OPTION	Resistance to Theft / Diversion by Unauthorized Parties	Technical Viability	Environment, Safety and Health	Cost Effectiveness	Timeliness	Fosters Progress & Cooperation with Russia and Other Countries	Public and Institutional Acceptance	B - Baseline; R - Reasonable; E - Eliminated
LTS-1 No Action	o	—	—	+	+	—	—	B
LTS-2 Upgrade Interim Facilities	o	o	o	o	o	o	o	R
LTS-3 Consolidate at DOE Sites	+	+	o	o	o	o	o	R
LTS-4 Non-DOE Domestic Sites	o	o	—	—	o	o	—	E

4.1.3. Options Determined to be Reasonable Alternatives for Long-Term Storage

(LTS-2) Upgrade of Interim Storage Facilities to make them Suitable for Long-Term Storage

Examples of existing sites where plutonium could continue to be stored and facilities could be upgraded include Idaho National Engineering Laboratory, Oak Ridge, Pantex, Savannah River, and Hanford. Upgrade of storage facilities at Los Alamos National Laboratory is already underway. Selection of this alternative would not necessarily require an upgrade of all storage facilities at all sites; some materials could be consolidated to reduce the number of sites involved and the overall costs. Upgraded facilities would be more likely to be viable for a 50 year period and transportation to alternative storage sites (prior to disposition actions) would be minimized. Major construction of new facilities (or partially completed unused facilities) would be avoided.

(LTS-3) Consolidation at DOE Sites

This option was rated high in resistance to theft or diversion to reflect the advantages in reducing the number of sites involved, and high in technical viability due to consolidation in a state-of-the-art storage facility where there would be little doubt that the facility would remain viable for the potential duration of the long-term storage. Despite the relatively high up-front costs, this option could have a reduced operating cost, with a potential for life-cycle cost savings.

4.1.4. Long-Term Storage Option Rated but Eliminated from Further Consideration

(LTS-4) Utilization of Existing Facilities at Non-Department-of-Energy Domestic Sites

This option was eliminated because of ES&H, cost, and public / institutional acceptance concerns, with no overriding advantages evident compared to existing DOE sites already safeguarding nuclear materials. Use of sites not currently under DOE cognizance would require substantial upgrades in infrastructure for handling and safeguarding of nuclear materials. Costs would increase and new ES&H requirements and concerns would be introduced with the support facilities (e.g., radioactive materials analytical laboratories, radioactive waste treatment facilities and nuclear material processing facilities) associated with long-term storage. It is judged that the public and other Government agencies would express concern over creating another DOE nuclear site when several are being phased out.

The ongoing Pantex Site-Wide Environmental Impact Statement that will evaluate alternatives for interim storage of plutonium pits may analyze other sites, including Department of Defense sites, as reasonable alternatives for interim storage of pits and weapon components. If any Department of Defense sites are determined to be reasonable for interim storage, then those sites will also be evaluated as candidate sites for long-term storage.

4.1.5. Long-Term Storage Option Disqualified from Further Consideration

(LTS-5) Utilization of Non-Domestic Sites for Long-Term Storage

This option is not able to address all the long-term storage requirements. The long-term storage requirements include the storage of the materials set aside as a strategic reserve for defense purposes, which are not appropriate to locate outside the U.S. This option was disqualified in the screening process because the risk of theft / diversion by unauthorized parties would be greater than those involved in the utilization of domestic sites. Safeguards and security of nuclear material are also enhanced by the domestic law enforcement infrastructure, which would not be as easily coordinated outside the U.S.

4.2 SCREENING OF PLUTONIUM DISPOSITION OPTIONS

4.2.1. Introduction

A total of 37 disposition options were evaluated to determine those considered reasonable alternatives for further evaluation in the Programmatic Environmental Impact Statement (PEIS), and in a detailed technical, economic, and non-proliferation evaluation process. These options were suggested by stakeholders and National Laboratories, or were gleaned from a review of prior work related to disposal of high level radioactive wastes. These options were grouped into five categories:

- 1- No Plutonium Disposition Action (Continued Storage)
- 1- Continued Storage with Enhanced Passive Security
- 13- Direct Disposal
- 6- Immobilization; then to Repository or Equivalent
- 16- Reactor Consumption, with Repository Disposal of Spent Fuel (Including 3 options with Accelerator Drivers)

From the options evaluated, a total of 13 options were disqualified for a "fatal flaw" in one or more criteria and therefore were not rated against all of the criteria.

Figure 4-2 is a summary chart showing the relative ratings among the remaining options versus the nine evaluation criteria. This chart is similar to the summary chart in the National Academy of Sciences review,¹ except this report includes options that were not in the National Academy of Sciences Study, and slight differences in the criteria. Additionally, ratings in this evaluation utilized "high" (+) as more desirable, whereas the National Academy of Sciences used "high" (black box) to refer to high risk.

Based on these ratings, eleven options were screened as reasonable alternatives for further evaluation, including:

- 2 - Direct Disposal
- 4 - Immobilization
- 5 - Reactor Consumption

Twelve of the options were eliminated as significantly less attractive than those selected as reasonable alternatives for further evaluation. The following sections summarize the screening evaluation results.

4.2.2. Baseline Option for Plutonium Disposition

(S-1) No Plutonium Disposition Action (Continued Storage)

This option is considered a "base" case, using adequate, proven Safeguards and Security protection. Other reasonable alternatives would have some more positive disposition actions to change the form and/or preclude the practical retrievability of the surplus plutonium and other fissile materials. Principal advantages of the option would be (1) low cost, (2) timely implementation, and (3) an ability to retrieve the material should current national policy for disposition of surplus weapons grade material change or should a decision be made to wait for maturing of a technology that will assure a high level of plutonium destruction. Principal disadvantages include the concerns that continued storage may not set an appropriate example of irreversible arms reductions.

¹ National Academy of Sciences, Committee on International Security and Arms Control, Management and Disposition of Excess Weapons Plutonium, National Academy Press, Washington, DC., 1994.

Figure 4-2. Relative Ratings among Plutonium Disposition Options

Legend Relative Ratings among Plutonium Disposition Options: + High o Medium — Low ? Uncertain		Resistance to Theft or Diversion in Processing/Storage	Resistance to Retrieval, Extraction and Reuse	Technical Viability	Environment, Safety and Health	Cost Effectiveness	Timeliness	Fosters Progress & Cooperation with Russia & Others	Public & Institutional Acceptance	Additional Benefits	B - Baseline; R - Reasonable; E - Eliminated
S-1	NO ACTION: CONTINUE STORAGE	o	—	+	+	+	+	—	—	o	B
S-2	RADIATION BARRIER ALLOY	+	o	o	—	o	o	o	—	o	E
D-2/3	DEEP BOREHOLE	+	+	?	+	o	o	o	—	o	R
D-7	CONTINENTAL MAGMA	+	+	—	—	o	—	—	—	o	E
D-11	SUB SEABED	—	o	—	+	o	—	—	—	o	E
D-13	DEEP SPACE LAUNCH	—	+	—	—	—	—	—	—	+	E
I-2	GLASS IMMOBILIZATION / DWPF	+	o	o	—	—	—	o	o	o	E
I-3	GLASS IMMOBILIZATION	+	o	o	o	o	o	o	o	+	R
I-4	CERAMIC IMMOBILIZATION	+	o	o	o	o	o	o	o	+	R
I-5	ELECTROMETAL. TREATMENT	+	o	—	—	o	o	o	o	+	R
I-6	GLASS OXIDATION/DISSOLUTION	+	o	—	o	o	o	o	o	+	R
R-1	EURATOM MOX	o	o	+	o	+	+	+	o	o	R
R-2	EXISTING LWR	o	o	+	o	+	+	+	o	o	R
R-2A	PARTIALLY COMPLETED LWR	o	o	+	o	o	o	+	o	o	R
R-3	EVOLUTIONARY OR ADV. LWR	o	o	+	o	o	o	+	o	+	R
R-5	MHR	o	+	—	o	o	—	o	—	+	E
R-6	CANDU	o	o	+	o	+	+	+	o	o	R
R-7	ALMR W/ PYROPROCESSING	o	o	o	—	—	—	—	—	o	E
R-8	ACCELERATOR / MOLTEN SALT	+	+	—	—	—	—	o	o	+	E
R-9	ACCELERATOR / PARTICLE BED	o	+	—	o	—	—	o	o	+	E
R-12	ACCELERATOR / MHR	o	+	—	o	—	—	—	o	+	E
R-14	PARTICLE BED REACTOR	o	+	—	o	—	—	o	—	+	E
R-15	MOLTEN SALT REACTOR	+	+	—	—	—	—	o	—	+	E

4.2.3. Options Determined to be Reasonable Alternatives for Plutonium Disposition

(D-2/3) Emplacement in Deep Boreholes

Potential use of deep boreholes (2 to 6 kilometers) is considered to merit further detailed evaluation. This type of option is currently being evaluated in other countries for high-level waste. The surplus fissile materials could be disposed in a total volume (much smaller than the current high-level waste repository) which would require a few deep boreholes. A choice would need to be made as to whether the surplus plutonium and other fissile materials should be directly loaded (Option D-3) into a disposal container for emplacement in the deep borehole (with physical separation or neutron poisons used to provide assurance against inadvertent criticality) or whether the surplus material should first be immobilized without radionuclides (Option D-2). Principal advantages would be (1) isolation from the biosphere and assurance against clandestine retrieval, (2) relatively low operational costs, and (3) timely completion after implementation. However, these latter two are offset by a potentially long and presumably costly period to further select and characterize a site and to license/permit the operations and site, particularly in light of the tremendous cost and time being taken to evaluate the suitability of Yucca Mountain as a mined geologic high-level waste repository.

(I-3) Immobilization in Borosilicate Glass

This option would utilize a new vitrification plant to commingle surplus fissile materials with other radionuclides (e.g., defense nuclear waste products) immobilized in borosilicate glass, resulting in a waste form that is much like a reference case for the high level waste repository. One variant of this option is to install a separate, new customized melter and other equipment at the Defense Waste Processing Facility at DOE's Savannah River Site to use existing facility infrastructure. Another variant would utilize a new facility to immobilize the plutonium without radionuclides in small canisters and placing the small canisters in DWPF canisters prior to filling them with vitrified high level waste.

Advantages for this option would be that it involves relatively mature technology, plus less processing, handling, and transportation (compared to reactor burning) to create an acceptable proliferation-resistant waste form (similar to spent fuel). No energy value would be recovered from the surplus plutonium.

(I-4) Immobilization in Ceramics

This option is similar to I-3, above, except that ceramic compounds would provide the immobilization medium, and there is less overlap in technologies being developed for other programs. Compared to I-3, this options is less mature and generates a waste form that differs from the reference case for the high level waste repository, but may provide superior long-term performance compared to borosilicate glass.

(I-5) Electrometallurgical Treatment

This option is also similar to I-3, above, except that electrometallurgical techniques would be used to prepare metal alloy castings or mineral forms as the immobilization medium. Currently installed equipment may be able to treat small quantities of certain forms of surplus plutonium. This technology is being considered for further development to treat spent fuels owned by the Department of Energy, which would provide the capability to treat more of the surplus plutonium inventory. Although it does not make sense to develop this technology further for the plutonium disposition mission alone, if it is developed for treating spent fuels, it will be evaluated for disposition of some or all of the surplus plutonium.

(I-6) Glass Material Oxidation and Dissolution System-GMODS

This option involves a relatively new immobilization technology that requires further development and scale up. Even though it is less mature than other immobilization options, it is recommended for further evaluation because of two potential significant advantages: (1) many plutonium-laden materials can be fed directly to the melter system without the pre-processing steps required for the borosilicate glass and ceramic options (I-3 and I-4, above), and (2) the surplus fissile materials could be directly co-mingled and immobilized with DOE defense nuclear spent fuel, thereby dealing with a significant separate disposal problem currently considered an environmental liability.

(R-1) Euratom Commercial MOX Fuel Market/Reactor Consumption

This option would involve transferring, under some Government to Government or Government/Commercial arrangement, surplus plutonium to a Euratom fuel manufacturer with existing capability to fabricate MOX fuel. The material would subsequently be burned in Euratom reactors and handled as spent fuel by the host country.

Significant advantages would include (1) proven, existing technology, (2) timely initiation and implementation, (3) cost effectiveness, and (4) the opportunity to encourage Russia to participate concurrently in a similar arrangement. Adequate safeguards and security assurances would have to be provided through Euratom and IAEA safeguards.

(R-2) Existing U.S. Light Water Reactors

This option would utilize U.S. commercial light water reactors with sufficient operating time to complete loading and burning mixed oxide (MOX) fuel containing plutonium. During the utilization period, some of the plutonium would be consumed (burned) and the remainder would be embedded in spent fuel. The spent fuel would be eventually emplaced in a high level waste repository. Significant advantages of this option would include (1) use of a mature technology and existing reactor plants that could be re-licensed for MOX fuel, (2) cost effectiveness, and (3) the ability for timely implementation once MOX fuel is fabricated. It is noted that this option (relative to immobilization) would involve an additional processing step (fabricating MOX fuel) prior to achieving a final product suitable for repository disposition but would result in no net increase in spent fuel in a repository. The MOX fuel could be fabricated in the U.S. in a new or modified facility or in a Euratom country, probably in an existing facility. The primary costs of this option are associated with the incremental costs of fabricating and burning MOX fuel rather than uranium fuel in these reactors.

(R-2A) Partially Completed Light Water Reactors

This option is similar to use of existing light water reactors (R-2) summarized above, except that partially completed plants would be finished and initially used for this application, possibly in conjunction with an operating plant. Actions would need to be completed to obtain an operating license, but siting and initial permitting are already in place. Advantages and disadvantages are the same as for existing LWRs, except that additional costs to complete the plant would have to be amortized, the timing to initiate the mission would be more uncertain, and additional spent fuel would be generated. MOX fuel fabrication alternatives are the same as for Option R-2. This option would only be attractive if sufficient existing reactor capacity was not available or utility agreements could not be obtained.

(R-3) Evolutionary or Advanced Light Water Reactors

This option is similar to use of existing U.S. light water reactors (R-2) summarized above, except that updated technology would be used and advanced light water reactors would have passive safety features. The fact that evolutionary or advanced light water reactors will complete the NRC certification (pre-approved license) process within the next several years means that a new plant might possibly be available concurrently with MOX fuel availability (provided reactor siting and permitting proceed in a timely fashion). Advantages of this option would be similar to those for existing or partially completed light water reactors. Disadvantages include up-front capital costs that would have to be amortized, potential siting/permitting issues that pose time uncertainty as to the completion of such plants and their operation, and additional spent fuel would be generated. MOX fuel fabrication alternatives are the same as for Option R-2. This option would only be attractive if sufficient existing reactor capacity was not available or utility agreements could not be obtained, and there were no available partially completed reactors or completion of these reactors was determined to be less attractive than building new reactors.

(R-6) CANDU Heavy Water Reactors

This option would involve utilizing existing Ontario Hydro CANDU heavy water reactors to burn MOX fuel containing surplus plutonium. The MOX fuel may be able to be fabricated in the U.S. at the Hanford FMEF facility due to the short length of the CANDU fuel assemblies; disposition of spent fuel would be carried out by Ontario Hydro in Canada. Advantages would be similar to those for using existing light water reactors in the U.S.: (1) mature technology with a safe operating record, (2) cost effectiveness, (3) a timely start, particularly if MOX fuel fabrication can start sooner using FMEF rather than with a totally new facility. Additionally, there is an opportunity to encourage Russia to participate in a similar approach for disposition of their surplus plutonium. A disadvantage of this option is that more intensive security and IAEA safeguards and verification would be required in implementation of this option because of international transportation, more frequent fuel handling and lower residual radiation levels in the CANDU spent fuel rods.

4.2.4. Plutonium Disposition Options Rated but Eliminated from Further Consideration

(S-2) Radiation Barrier Alloy for Indefinite Storage

Although this option would provide by design significant additional resistance to theft or diversion during indefinite storage, it was eliminated as a disposition option because it did not have an "end-point" destination comparable to direct disposal, immobilization, or reactor burning options. The Committee noted the material (a plutonium-beryllium compound) would be in a form unsuitable for a civilian high level waste repository unless "reconverted" to remove the plutonium and process it into a repository-compatible waste form.

(D-7) Injection into Continental Magma

The technology is very immature; a licensing and regulatory regime is undefined and uncertain; and would present several environmental, safety, and health concerns. All of these factors would also make the schedule very uncertain.

(D-11) Emplacement in the Sub-Seabed

The technical approach is immature, and a licensing and regulatory regime is undefined and uncertain, which also make the schedule uncertain. Extended operations at sea would enhance the opportunities

for a transportation vessel accident in which material lost at sea could be available for retrieval by others, but also more difficult for the U.S. to retrieve and control. Public/International perceptions are also uncertain due to similar concerns as other Ocean Disposal options.

(D-13) Launching to Deep Outer Space

Despite the promise of removing all the surplus material from our planet via this approach, major concerns were considered overriding. First, based on U.S. experience to date, the risk of an explosion during launch and off site dispersal of radioactive material would be much higher than the risks of accidents and dispersal of radioactive materials for other options. Secondly, if the space vehicle with its surplus fissile material payload failed to achieve orbit and re-entered the atmosphere, the chances of other nations recovering the material would be enhanced and the chances of U.S. retrieval would be reduced. Additionally, this option would be more expensive and less timely to complete than many others.

(I-2) Immobilization with Radionuclides in Borosilicate Glass. Use of Modified DWPF

This option is similar to option I-3 which would use a new vitrification facility. In this option, the present Defense Waste Processing Facility (DWPF) at Savannah River Site, would have to have a new, specially designed melter installed and much of the supporting equipment re-fitted for this application during or after its present mission because DWPF was not designed for criticality control. This would create additional total personnel radiation exposure and potentially interfere with the defense waste processing mission, resulting in delays and cost escalation. (Note: If a new melter facility were considered for the DWPF site and used existing infrastructure, this would be a "new" facility evaluated under Option I-3.)

(R-5,7,8,9,12,14,15) Reactor Options

(1) Five new reactor burning options requiring significant technology development, including three concepts with accelerators coupled to reactors, were eliminated primarily due to their technical immaturity, and the attendant costly and lengthy development and demonstration effort which would be required to bring them to a viable, practical status and enable disposition options to be initiated with certainty. Although these options hold promise of higher levels of plutonium destruction (burn-up) than other reactor burning options, the increased percentage of plutonium burn-up that could be achieved is not worth the time delay or increased cost, particularly in light of the technical uncertainties, and the more timely availability of other mature reactor burning options to achieve the spent fuel standard. However, if some of these advanced concepts are developed and successfully operated for other missions (such as for commercial nuclear power) they will be considered for plutonium disposition as well.

These five options were:

- (a) Accelerator Conversion: Molten Salt Target (R-8),
- (b) Accelerator Conversion: Particle Bed Target (R-9),
- (c) Accelerator-Driven Modular Helium Reactor (R-12),
- (d) Particle Bed Reactor (R - 14),
- (e) Molten Salt Reactor (R - 15).

(2) (R-5) Modular Helium Reactors

A reactor burning concept was evaluated that involves Modular Helium Reactors (MHRs) coupled to closed Brayton cycle power conversion systems (PCSs). This option is less technically mature than

other available options using MOX fuel in operating water-cooled reactor plants. The MHR would use tested, but not fully demonstrated or proven, ceramic-coated plutonium oxide fuel particles in a graphite matrix. The power conversion system would use components (e.g. turbine with long, heavy rotor and active magnetic bearings) that have neither been tested as a "system" themselves nor integrated with a gas-cooled reactor system.

The concept could achieve higher levels of plutonium destruction than water-cooled reactors (without reprocessing) if this concept were developed and successfully operated. However, the technical uncertainty, cost, and time to develop, license, and successfully operate this new integrated reactor plant and power conversion system is not justified since plutonium disposition can be accomplished using existing technologies. If this concept is developed and successfully operated for other missions, it will be considered for plutonium disposition as well.

(3) (R-7) Advance Liquid Metal Cooled Reactor with Pyroprocessing

A reactor-burning concept was evaluated that involves a variation of the Integral Fast Reactor concept whereby an Advanced Liquid Metal Cooled Reactor with a plutonium alloy metal fuel would operate on a once through cycle and then utilize pyroprocessing techniques to make a plutonium-rich high-level waste form for potential disposal in a repository. This concept, which would use a reactor fuel cycle design still under development in a manner different from its intended purpose, would be more costly and less timely than other mature water reactor options. The development program was recently terminated by Administration and Congressional action. Since the plutonium disposition can be accomplished using existing technologies, there is no justification for developing this advanced technology for the purpose of plutonium disposition. However, if it is developed and successfully operated for other missions (such as for commercial nuclear power) it will be considered for plutonium disposition as well.

4.2.5. Plutonium Disposition Options Disqualified Prior to Rating

A number of options were considered in an initial evaluation and were determined to not meet a minimum threshold for rating versus all the criteria because the disqualification factor for one or more criteria indicated a "fatal flaw". The options disqualified, and the principal reasons therefore, were:

(D-1) Direct Emplacement (without immobilization) in a High Level Waste Repository.

It is highly unlikely that a determination of the acceptability of this non-reference waste form would be made before the Yucca Mountain (or equivalent) repository opens, such that disposition could not start within 15 years. Since material would not have a radiation barrier, the requirement that the civilian high level waste repository remain unsealed for 100 years would make the material retrievable (during that period), giving this option no advantage over long-term storage for that period. As a result, this option would not meet the spent fuel standard.

(D-4) Discard to WIPP of Surplus Plutonium

Pursuing this option for approximately 50 MT of surplus plutonium and complying with current ES&H regulations would exceed the remaining WIPP capacity after meeting the needs for disposal of defense-related transuranic (TRU) wastes currently committed or identified by DOE's Office of Environmental Restoration and Waste Management. While it is possible to consider a regulatory/licensing expansion of WIPP capacity, this would likely result in unacceptable disruptions, delays and increased costs for this important waste management program. By contrast, WIPP would provide a potentially desirable option for disposal of lesser quantities of TRU or equivalent surplus fissile materials (including plutonium waste residues) which cannot readily be converted into a material

form (e.g. MOX fuel) suitable for disposition options that can accommodate larger quantities of surplus plutonium.

(D-5) Hydraulic Fracturing

This approach (high pressure injection of slurried materials into fractured shale formations) was previously tested and evaluated for civilian high level waste disposal. The Committee concluded that there was no assurance of demonstrating technical feasibility of this unproven approach in time for the option to be considered in the decision process. No engineered barrier would exist to assure prevention of leakage into subsurface aquifers.

(D-6) Injection of Slurry into Deep Wells

This option, similar to Option D-5, would not have an engineered barrier to assure prevention of leakage into subsurface aquifers, and therefore would pose unacceptable ES&H risks.

(D-8) Melting into Crystalline Rock

Information previously developed in initially evaluating this approach for disposal of civilian high-level waste (spent fuel) by using the heat from the fuel to melt into rock formations was reviewed. It was concluded that the approach is not technically viable for this disposition application because of major uncertainties, primarily criticality concerns and assuring enough heat was available from spent fuel (to be commingled with the surplus fissile materials) to melt the host rock.

(D-9) Disposal Under Ice Caps

This option is not considered technically viable (not licensable or equivalent) and poses unacceptable ES&H risks since ice caps in Greenland and Antarctica are not necessarily stable beyond a few hundred years. Reaching agreement with Denmark to dispose of our nuclear materials on Greenland is not likely; a current treaty already prohibits leaving nuclear wastes in Antarctica.

(D-10) Seabed Disposal and

(D-12) Controlled Dilution in Oceans

These options are disqualified primarily because compliance with ES&H regulations are unlikely. Because of increasing concerns about pollution of marine environments (and the related food chain) with radioactive materials, the US EPA has not issued in recent years any permits for ocean dumping or dispersal of radioactive materials. This is consistent with US law which implements the "Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter", generally known as the London Dumping Convention, enacted in 1975 and amended in 1980 and 1993.

(I-1) Underground Nuclear Detonation

This option was disqualified because of compliance with regulatory and licensing requirements is regarded as very uncertain and compliance with ES&H regulations is unlikely for a new process of this type. In addition, the U.S. has a moratorium on underground nuclear testing and declared U.S. policy is to negotiate a Comprehensive Test Ban Treaty; the Committee judges it unlikely that detonations for this application would be approved since such actions might undermine this national policy.

(R-4) Naval Nuclear Fuel: Burning Plutonium in Naval Reactor Plants

There is no design, testing or demonstration experience with MOX fuel in Naval reactors. Even if technical feasibility had been demonstrated, new classified fuel and reactor core fabrication plants would be required. Since these processes and facilities cannot be declassified, transparent confirmation of the process or final condition by international inspections would not be possible. Additionally, the number of new fuelings of Naval reactor plants (which use very long lived cores) is so small that disposition of surplus plutonium could not be accomplished in a rational time frame (much greater than 30 years from a decision to implement this option).

(R-10/11) Reprocessing: Burning Plutonium in Existing or New Evolutionary/Advanced Light Water Reactors with Chemical Reprocessing of Spent Fuel

If reprocessing is used to separate plutonium from spent fuel to fabricate more fuel, there are stages in the processing and handling where weapons-usable materials are more vulnerable to theft or diversion than the “stored weapons standard.” Additionally, the time and cost required to design and construct reprocessing plants for this application are much greater than those for available, adequate options that meet the spent fuel standard.

(R-13) Advanced Liquid Metal Reactor (ALMR) with Recycle and Reuse of Metallic Alloy Fuel Elements

Based on recent DOE and Congressional action, development of the ALMR/IFR reactor concept is no longer being pursued due to a U.S. nonproliferation policy not to develop technologies that rely on plutonium recycle. Since this is a relatively immature reactor concept that has not been demonstrated and since the plutonium disposition can be accomplished using existing technologies, there is no justification for developing this advanced technology solely for the purpose of plutonium disposition. However, if it is developed and successfully operated for other missions (such as for commercial nuclear power) it will be considered for plutonium disposition as well.

4.3. SCREENING OF HIGHLY ENRICHED URANIUM DISPOSITION OPTIONS

4.3.1. Introduction

A total of nine disposition options for surplus highly enriched uranium were evaluated to determine those considered reasonable alternatives for further evaluation in a separate Environmental Impact Statement (EIS) for HEU disposition, and in a detailed technical, economic, and non-proliferation evaluation process. While many of the same options evaluated for plutonium could have been also analyzed for HEU disposition, a more limited number of options were considered because the options disqualified or eliminated for plutonium disposition were viewed as also being unreasonable for disposition of highly enriched uranium.

Two factors significantly impact the disposition of surplus highly enriched uranium, and result in options that were not available for disposition of other weapons-usable materials:

- The highly enriched uranium can be rendered non-weapons-usable by simple isotopic dilution to low enriched uranium.
- There is a substantial domestic market for low enriched uranium, which provides opportunities for net revenues to the U.S. Treasury through sale of the highly enriched uranium or the blended product that meets specifications of the commercial market.

The options for disposition of surplus highly-enriched uranium considered in the screening evaluations include the following:

- (H-1) No HEU Disposition Action (Continued Storage)
- (H-2) Direct Sale of HEU (buyer to blend to LEU)
- (H-3) Emplacement of HEU in Deep Boreholes
- (H-4) Vitrification of HEU with High Level Waste
- (H-5) Blend to LEU (19% Enrichment) and Store Indefinitely
- (H-6) Blend to LEU (19% Enrichment) and Sell the LEU
- (H-7) Blend to LEU (~5% Enrichment) and Store Indefinitely
- (H-8) Blend to LEU (~5% Enrichment) and Sell the LEU
- (H-9) Blend to LEU (19% or Less Enrichment) and Discard as Waste

None of the options was disqualified as having a "fatal flaw."

Figure 4-3 is a summary chart showing the relative ratings among the options versus the nine evaluation criteria. Based on these ratings, four of the nine options were determined to be reasonable alternatives for further evaluation. Four of the nine options were eliminated based on multiple low ratings and judgments that they were significantly less desirable. (In addition, No Disposition Action is to be carried forward as a baseline for evaluations.) The options eliminated would not recover any of the energy value or near-term monetary value from the highly enriched uranium to support National budget reduction objectives.

Figure 4-3 Relative Ratings among HEU Disposition Options

LEGEND Relative Ratings among HEU Disposition Options: + High o Medium — Low	Resistance to Theft	Resistance to Retrieval	Technical Viability	ES&H	Cost Effectiveness	Timeliness	International Cooperation	Public/Institutional Acceptance	Additional Benefits	B - Baseline; R - Reasonable; E - Eliminated
H-1 Store HEU	O	—	+	+	O	+	—	—	O	B
H-2 Sell HEU	O	+	+	+	+	+	+	+	O	R
H-3 Deep Borehole	O	O	—	O	—	—	—	—	O	E
H-4 Vitrify HEU w/HLW	O	O	—	—	—	—	—	—	O	E
Blend to ~ 19%										
H-5 Store ~ 19%	+	+	+	+	O	+	O	—	O	E
H-6 Sell ~ 19%	+	+	+	+	+	+	+	+	O	R
Blend to ~ 5%										
H-7 Store ~ 5%	+	+	+	+	O	O	O	—	O	E
H-8 Sell ~ 5%	+	+	+	+	+	O	+	+	O	R
H-9 Blend to < 19%, Discard	+	+	O	O	—	O	—	—	O	R

4.3.2. Baseline Option for HEU Disposition

(H-1) No HEU Disposition Action (Continued Storage)

This option is considered a “base case” for disposition alternatives. It would continue to use adequate and proven safeguards and security protection. Other reasonable alternatives would have more positive actions to change the form to reduce the potential for reuse in a weapon, enable utilization of the energy content and recovery of some monetary value from this material. Principal disadvantages include the concerns that continued storage may not set an appropriate international example of irreversible arms reductions.

4.3.3. Options Determined to be Reasonable Alternatives for HEU Disposition

(H-2) Direct Sale of HEU (with buyer to blend to LEU)

This option assumes that a licensed commercial vendor would purchase the material and blend it down for use as low enriched uranium in the commercial nuclear fuel supply chain. In this scenario, the approach has several obvious advantages: (1) the possibility of retrieval and reuse would be quickly

eliminated, (2) the Government would recover monetary value in the near-term, (3) implementation would be relatively short, and (4) it matches current initiatives with Russia.

(H-6) Blend to LEU (19% Enrichment) and Sell

In this option, the Government would perform the blending operation or procure blending services. The advantages of this option are: (1) quickly eliminating the possibility of retrieval and reuse, (2) eliminating any potential ES&H vulnerabilities associated with storage, (3) recovering the monetary value for the uranium in the near term, and (4) effecting additional international cooperation since it matches a current approach with Russia.

(H-8) Blend to LEU (~5% Enrichment) and Sell

This option is essentially the same, and has the same advantages, as blending to 19% and selling the material, except blending to a lower enrichment may take more time. On the other hand, the product is more directly usable for commercial reactor fuel.

(H-9) Blend to LEU (19% Enrichment or Less) and Discard as Waste (for HEU with commercial value)

This option is a reasonable alternative for the limited purpose of the disposition of HEU in forms or conditions with no commercial value. It may be the only reasonable alternative for HEU with impurities or in forms that would be expensive to purify the material to meet specifications for commercial uranium. The blending eliminates the risk of reuse of the material in weapons. Blending below 19% may be desired to avoid any criticality concerns associated with the waste form.

4.3.4. HEU Disposition Options Rated but Eliminated from Further Consideration

Four options were eliminated based on multiple low ratings and/or conclusions that they were significantly less desirable than the reasonable options discussed above (i.e. were clearly dominated by similar reasonable options). Since HEU has economic value as a fuel for nuclear power plants while plutonium currently does not, none of these disposal option can be justified for HEU while they can be justified for plutonium.

(H-3) Emplacement of HEU in Deep Boreholes

This option would be similar to the deep borehole option considered for plutonium disposition. In the case of HEU, it received a low rating on technical viability relative to blending options for HEU disposition. It did not rate as high as blending options in resistance to retrieval and reuse since it is more reversible than isotopic blending. It would not recover monetary value, it would create siting and licensing challenges and would not likely foster cooperation with Russia.

(H-4) Immobilization of HEU with High Level Waste

This option would be similar to the immobilization options considered for plutonium disposition. The technology for immobilizing HEU is less mature than blending options and would take much longer and cost much more than other reasonable alternatives. It did not rate as high as blending options in resistance to retrieval and reuse since it is more reversible than isotopic blending. It would involve ES&H vulnerabilities associated with handling high level wastes. It would not recover monetary value and would not likely foster cooperation with Russia.

(H-5) Blend to LEU (19% Enrichment) and Store Indefinitely

This option is similar to option H-6, above, except the material would be indefinitely stored instead of sold in the near term. A significant disadvantage is that the monetary value would not be recovered if the material is stored indefinitely, even though the potential value is retained. Public and institutional endorsement would not be likely since near-term monetary value would not be recovered. This option is eliminated because it is clearly less attractive than Option H-6 which would recover near-term monetary value for the Government.

(H-7) Blend to LEU (~5% Enrichment) and Store Indefinitely

This option is similar to Option H-8, above, except that the material would be indefinitely stored instead of sold in the near term. The same disadvantages and concerns cited for Option H-5, above, apply. This option is therefore eliminated because it is clearly less attractive than Option H-8 which would recover near-term monetary value for the Government.

4.4. SCREENING OF U-233 AND OTHER MINOR ACTINIDE DISPOSITION OPTIONS

The proposed scope of the overall disposition program included fissile materials that did not result from weapons dismantlement, including uranium-233 and other minor actinides (e.g., americium). It was determined that there were not sufficient inventories of surplus minor actinides to represent a significant proliferation threat. Therefore, the screening evaluations were focused on options for disposition of surplus U-233.

4.4.1. Introduction

A total of eight options for Uranium-233 were evaluated to determine those considered reasonable for further evaluation in the PEIS and in a detailed technical, economic, and non-proliferation evaluation process. While many of the options evaluated for plutonium disposition could also have been analyzed for U-233 disposition, a more limited number of options were considered because the options disqualified or eliminated for plutonium disposition were viewed as also being unreasonable for disposition of U-233.

Three factors significantly impact the options available disposition of U-233:

- Uranium-233 can be isotopically diluted with uranium-238 to ~10% or less U-233 to render it unusable in weapons.
- There is no commercial use of large quantities of U-233 in either concentrated or isotopically diluted form.
- Several of the plutonium disposition options may also be able to accommodate the U-233 inventories.

The options for disposition of Uranium-233 considered in the screening process include the following:

- (U-1) No U-233 Disposition Action (Continued Storage)
- (U-2) Nitrate Blend-Down to ~10% U-233, Storage of Blended Product
- (U-3) Nitrate Blend-Down to ~10% or less U-233, Disposal of Blended Product as Waste
- (U-4) Discard to the Waste Isolation Pilot Plant (WIPP)
- (U-5) Emplacement of U-233 in Deep Boreholes
- (U-6) Discard to Liquid High Level Waste Tanks
- (U-7) Immobilization with High Level Waste and Emplacement in High Level Waste Repository
- (U-8) DOE Reactor Irradiation

From the options evaluated, one option (U-6) was disqualified for a “fatal flaw.” Figure 4-4 is a summary chart showing the relative ratings among the U-233 disposition options versus the nine screening criteria. Based on these ratings, three of the options were determined to be reasonable alternatives for further evaluation. Three of the options were eliminated based on multiple low ratings or judgments that they were significantly less desirable compared to other available options.

Figure 4-4. Relative Ratings for Uranium-233 Disposition Options

OPTION	<div style="border: 1px solid black; padding: 10px; width: fit-content;"> <p>LEGEND</p> <p>Relative Ratings among U-233 Disposition Options:</p> <p>+ HIGH</p> <p>o MEDIUM</p> <p>— LOW</p> </div>									
	Resistance to Theft / Diversion by Unauthorized Parties	Resistance to Retrieval, Extraction, and Reuse by Host Nation	Technical Viability	Environment, Safety and Health	Cost Effectiveness	Timeliness	Fosters Progress & Cooperation with Russia and Other Countries	Public and Institutional Acceptance	Additional Benefits	B - Baseline; R - Reasonable; E - Eliminated
U-1 No Action: Continued Storage	o	—	+	o	+	+	—	—	+	B
U-2 Blend to 10%, Store	+	+	+	o	+	+	o	—	o	R
U-3 Blend to ≤10%, Dispose	+	+	+	o	+	+	o	o	o	R
U-4 Discard to WIPP	+	o	+	+	o	o	o	o	o	R
U-5 Deep Borehole Emplacement	o	o	—	+	o	—	o	—	o	E
U-7 Immobilization with HLW	o	o	o	o	—	—	o	o	o	E
U-8 DOE Reactor Irradiation	o	o	o	o	—	—	o	o	o	E

Two of these eliminated options (U-5 and U-7) were considered to be unreasonable for the sole mission of uranium-233 disposition. However, if these approaches are selected for plutonium disposition, there may be low incremental impacts to also use them for U-233. Therefore, the analysis of these options for plutonium disposition should include the possibility that U-233 inventories are also treated in this manner.

4.4.2. Baseline Option for U-233 Disposition

(U-1) No U-233 Disposition Action (Continued Storage)

This option is considered a “base case” for U-233 disposition alternatives. It would involve a continuation of the long-term storage alternatives discussed in Section 4.1. It would continue to use adequate and proven safeguards and security protection. Other reasonable alternatives would have more positive actions to change the material form to reduce the reliance on institutional controls and reduce the potential that these materials could be used in a weapon.

4.4.3. Options Determined to be Reasonable options for U-233 Disposition

(U-2) Nitrate Blend-Down to 10% U-233, Storage of Blended Product

This option assumes that the material is blended down to ~10% to preclude use in weapons prior to placing the material in indefinite storage. Advantages of this technically viable approach are that the possibility of retrieval and use in weapons would be quickly eliminated at a relatively low cost.

(U-3) Nitrate Blend-Down to 10% or less U-233, Disposal of Blended Product as Waste

This option is similar to Option U-2, above, except the material would be sent to a waste repository instead of indefinitely stored. Also, the U-233 might be blended to lower concentrations to prevent any chance of criticality of the waste form. Principal advantages are the same as those cited for Option U-2.

(U-4) Discard to the Waste Isolation Pilot Plant (WIPP)

This option would utilize the WIPP facility for the relatively small quantities of U-233 consistent with the mission of WIPP to dispose of transuranic wastes, presuming U-233 can be designated as equivalent to transuranic waste. Resistance to proliferation would be achieved by dispersal of small quantities of material in many waste packages prior to facility closure, and by geologic barriers as well after closure of the facility. Advantages include the use of facilities and infrastructures that will be established in any case.

4.4.4. U-233 Disposition Options Rated but Eliminated from Further Consideration

Three options were eliminated based on multiple low ratings and/or conclusions that they were significantly less desirable than the reasonable alternatives discussed above (i.e., they were clearly dominated by similar, more desirable options).

(U-5) Emplacement of U-233 in Deep Boreholes

This option has less technical maturity than other U-233 disposition options and would require extensive licensing and regulatory approvals, making it less timely to implement than options that blend the U-233 to a form that cannot be used in weapons.

(U-7) Immobilization with High Level Waste and Emplacement in High Level Waste Repository

This option has not been demonstrated for U-233 and therefore has less technical maturity than other options, making it less timely to implement than other options.

(U-8) DOE Reactor Irradiation

Although the resultant product would likely meet the spent fuel standard, this option is considerably less cost-effective and less timely than the blending options

discussed above. Also, there is no operating DOE reactor that can irradiate the full length of the presently unirradiated fuel rods containing U-233.

4.4.5. U-233 Disposition Option Disqualified Prior to Rating

(U-6) Discard to Liquid High Level Waste Tanks

This option was disqualified for technical viability considerations. The waste tanks were not intended to contain significant quantities of fissile materials and are not designed to assure criticality control.

APPENDIX A. PUBLIC AND STAKEHOLDER INVOLVEMENT

Public input on a proposed set of screening criteria was solicited to assure that a comprehensive range of considerations was used to evaluate potential options for the long term storage and disposition of weapons-usable fissile materials.

Two questionnaires were developed (one for long term storage and the other for disposition) to determine the views of the interested public on the relative importance of the proposed screening criteria, additional criteria that should be used, and why any of the proposed criteria may be inappropriate or unnecessary. The questionnaires are included in Sections A.3 and A.4. One thousand copies of each questionnaire were included in the materials provided to people attending the 12 Scoping Workshops held during August through October, 1994. Approximately 150 of each questionnaire were completed and returned.

In addition to public input via these questionnaires, there was input on the proposed screening criteria captured in the transcripts of discussions at the Scoping Workshops.¹ There was also input regarding criteria contained in written comments submitted to the Department during the public comment period on the Notice of Intent to prepare a Programmatic Environmental Impact Statement.²

A.1 SUMMARY OF PUBLIC INPUT

Questionnaire respondents were asked to rate each of the criteria as Very Important, Moderately Important, Less Important, or Inappropriate or Unnecessary, and rank the criteria in order of importance. The complete set of input from the questionnaires is provided in Appendix A, which includes a tally of the ratings and rankings, and a listing of the written input on any additional criteria, inappropriate criteria and other comments. There was a significant diversity of responses, but some general themes that were represented in the public input are listed below.

Some of the comments included in the questionnaires were not specifically related to the screening criteria. These comments were integrated into the comment tracking system that compiled the other input received during the public comment period.

A.1.1 Results from Long Term Storage Questionnaire

Based on the criteria ratings and rankings, the first three storage criteria (Resistance to Theft, Technical Viability, and ES&H) were viewed as the most important.

A number of additional criteria were suggested. The criteria that were suggested most include:

- Minimization of Transportation
- Protection Against Natural Disasters
- Resistance to Reuse / Form of Stored Material
- Retrievability for Future Reuse

¹U.S. Department of Energy, DOE/MD-0001, "Scoping Meeting Comment Summary Report," November 30, 1994.

²Federal Register, Vol. 59, No. 118, June 21, 1994, p. 31985 - 31990.

- Social, Cultural, and Socioeconomic Impacts

Reasons given for proposed criteria being inappropriate included:

- ES&H is a requirement - should not traded-off with other factors.
- Timing for Long Term Storage is not urgent as long as safe, secure interim storage is achieved.
- Public knowledge is not sufficient and Public Acceptance is too difficult to measure to be a useful criterion.

Additional Comments included the following general themes:

- Consider using other existing government facilities for storage.
- Pre-treatment/packaging of materials to meet storage criteria should be included in scope of analysis, along with options for storage forms.
- Long Term Storage is not necessary if timely disposition actions are taken.

A.1.2 Results from Disposition Questionnaire

Based on the criteria ratings and rankings, the first four disposition criteria (Resistance to Theft, Resistance to Retrieval & Reuse, Technical Viability, and ES&H) were viewed as the most important.

A number of additional criteria were suggested. The criteria that were suggested most include:

- Various specific ES&H factors (waste minimization, transportation safety, repository issue)
- Degree of fissile material destruction
- Impact on U.S. long-term energy needs

Reasons given for proposed criteria being inappropriate included:

- Retrieval for Reuse may be a desirable feature.
- 20 and 50 years to start and finish, respectively, are much too long.
- Additional Benefits should not influence the decision.

Additional Comments included the following general themes:

- Disposition schedule goals should be much shorter.
- The Russian material poses the most pressing problems. The U.S. should not take actions without Russia reciprocating.
- Energy policy issues should be included and energy value from the surplus fissile materials should be extracted.
- The policy regarding plutonium recycle should be reconsidered.

A.1.3 Input from Scoping Workshops and Written Comments

Input from the Public Scoping Workshops and written comments were also reviewed for insights that related to the screening process. This input reinforced the general themes provided through the questionnaires outlined above.

A.2 IMPACTS OF PUBLIC INPUT ON SCREENING CRITERIA

Several additional criteria were considered as a result of the public input. Many of them were already captured within the scope of the original criteria and associated factors (see Section 2) but not specifically itemized in the questionnaires (e.g., minimization of transportation and specific ES&H impacts).

The public input on why some criteria may be inappropriate was reviewed. While some arguments had merit, there were significant inputs that considered these criteria to be very important. Therefore, the basic framework of the criteria was retained, with some modifications discussed below.

Due to the many respondents viewing the importance of shorter disposition time periods, the evaluations were based on desiring shorter development and implementation times than the 20 and 50 years proposed. This resulted in higher ratings for options that would utilize more mature technologies.

The screening process did not require a formal establishment of weighting factors for the criteria. Rather, the results of the rating of the options (see Section 4) allowed the screening decisions to be based on eliminating options that had low ratings for a significant number of the criteria or were dominated by similar, more acceptable options. Therefore, the analysis did not require determining the relative importance or rank order of the criteria. However, the next phase of the analysis will build on the screening criteria to evaluate the reasonable alternatives being analyzed in the NEPA evaluations and the technical, economic, and non-proliferation analyses to establish preferred alternatives. This will require determination of the relative importance of the criteria and therefore will benefit from the information developed from the questionnaires.

As a result of the input received, a number of the criteria were modified to clarify the criteria definition. The first criterion was modified to make it clear that the concern was theft / diversion of weapons-usable material by unauthorized parties (terrorists, sub-national groups, or disgruntled employees).

The second disposition criterion was modified to clarify that the concern was the potential of retrieval and reuse by the host nation for reversing the arms reduction process. For actions contemplated in the NEPA evaluations, the host nation is the U.S. for most options.

The criterion for both long term storage and disposition that was defined as "Influence" on Russia and Other Countries was re-worded as "Fostering Progress and Cooperation with Russia and Other Countries" to clarify the intent of this influence.

The final criteria applied to the screening process are discussed in detail in Section 2 of this report.

A.3 LONG TERM STORAGE SCREENING CRITERIA QUESTIONNAIRE

Storage & Disposition of Weapons-Usable Fissile Materials <i>Questionnaire</i>
<p><i>Screening Criteria for Determining Reasonable Alternatives for <u>Long-Term</u> Storage of Fissile Materials</i></p> <p>In Fall 1994 the Department of Energy will determine which alternatives for long term storage of weapons-usable fissile materials (primarily plutonium and highly-enriched uranium) will be included in a detailed decision process involving a Programmatic Environmental Impact Statement (PEIS) as described in the Notice of Intent (NOI) published in the Federal Register on June 21, 1994.</p> <p>Building on the long term storage evaluations initiated under the DOE Nuclear Weapons Complex Reconfiguration program, a screening process will be used to rule out unreasonable alternatives, based on the criteria outlined in this questionnaire. Stakeholder and public comments on the screening criteria are invited via return mail. A summary of the input received and the results of the screening process will be published in the PEIS Implementation Plan in early 1995.</p> <p>Long term storage alternatives considered in the screening process will include alternatives identified for the Reconfiguration program (as summarized in the NOI), and any other alternatives identified in the PEIS scoping process. Each alternative will be evaluated against each of the criteria described below (modified or refined based on input received).</p> <p>An alternative will be considered to be unreasonable for further evaluation if it is unacceptable in any of the criteria, or ranks so low overall compared to other alternatives that it does not merit further detailed evaluation.</p>	
<p>U.S. Department of Energy, Surplus Fissile Materials Project, 1000 Independence Ave., SW, Washington, D C 20585</p>	

Questionnaire

Regarding Criteria for Screening Long Term Storage Alternatives

Seven criteria are proposed for determining reasonable long term storage alternatives for weapons-usable fissile materials. Please indicate your views on the *relative* importance of each of the proposed criteria by marking the appropriate box, and also rank the criteria in order of importance (1-7, with 1 being most important) in the spaces provided.

	Very Important	Moderately Important	Less Important	Inappropriate or Unnecessary	Rank Order
1. <u>Resistance to Theft or Diversion</u> : The site and facility must be capable of providing for comprehensive protection and control of weapons-usable fissile materials.	☐	☐	☐	☐	_____
2. <u>Technical Viability</u> : There should be a high degree of confidence that a facility and site infrastructure can provide storage of nuclear components and materials for ~ 50 years.	☐	☐	☐	☐	_____
3. <u>Environmental, Safety & Health Compliance</u> : High standards of public and worker health and safety, and environmental protection must be met, and significant additional ES&H burdens should not be created.	☐	☐	☐	☐	_____
4. <u>Cost Effectiveness</u> : Long term storage should be accomplished in a cost-effective manner, and be compatible with reasonable disposition alternatives.	☐	☐	☐	☐	_____
5. <u>Timeliness</u> : Long term storage should be implemented in a timely manner.	☐	☐	☐	☐	_____
6. <u>Influence on Russia and Other Countries</u> : A facility must allow international inspections, and provide a good example for achieving appropriate standards for storage and protection of international nuclear material inventories.	☐	☐	☐	☐	_____
7. <u>Public and Institutional Acceptance</u> : An alternative should be able to muster a broad and sustainable consensus on the manner in which long term storage is accomplished.	☐	☐	☐	☐	_____

Are there any additional criteria that should be used to evaluate potential long term storage alternatives?
(Please include brief definition and rate using the same scheme as above)

	☐	☐	☐	☐	_____
	☐	☐	☐	☐	_____

If any of the criteria are viewed as inappropriate or unnecessary, please provide a brief explanation:

Additional Comments:

(Optional)

Name _____

Affiliation _____

Address _____

Phone _____

Please fold & staple and mail by October 17, 1994 to assure your input is included (no postage necessary)

Relative Importance:	Theft / Diversion	Technical Viability	ES&H	Cost	Time	Internat'l Influence	Public / Institutional			
Very Important	118	99	104	29	41	51	41			
Moderate	17	35	25	68	60	47	55			
Less Important	4	5	7	33	34	35	35			
Inappropriate	0	0	1	8	5	4	6			

Storage Criteria Importance Ratings

(143 Questionnaires Returned)

Rank	Theft / Diversion	Technical Viability	ES&H	Cost	Time	Internat'l Influence	Public / Institutional				
1	45	11	38	7	6	8	7				
2	28	36	27	9	8	6	5				
3	19	34	23	10	8	16	8				
4	13	23	14	20	18	15	14				
5	10	10	9	20	35	14	22				
6	3	3	6	27	28	23	31				
7	2	3	3	26	18	37	33				

Storage Criteria Rankings

(143 Questionnaires Returned)

Comments from Long Term Storage Questionnaire

Additional Criteria

Notations in parentheses: (Relative Importance [V,M,L] / Rank Order [1-7])
[multiple entries reflect multiple inputs]

ES&H and Security

- High safeguards and security. (V/1)
- Resistance to dispersal by high or nuclear explosive. (V/1)
- Surveillance of Stored Materials: Storage of surplus materials must allow periodic inspections to ensure that materials are in the as-expected condition and have not deteriorated during storage. Repackaging and restabilization capability must be available. (V/3)
- Monitorable with instruments to ensure environmental protection (V)
- Add transportation. (M,V)
- Transportation should be broken out into a separate, distinct criterion (V)
- Insure a safe method of transport (V/3)
- Minimal Transportation of materials (V/4)
- Minimize Transportation (M,M,M)
- Site locations must not require large amounts of transportation (V/2)
- Protection against natural disasters. (V/1)
- Area not subject to earthquakes, minimum ground water (flooding) concerns (V)
- Hurricane, tornado, earthquake-proof buildings created (?)
- Protection against destruction (V/1)
- Absolute safety (V)
- Low population density (V/1)
- Buffer Zone (V/3)
- Isolation of storage sites from community. (M/6)
- Water use (V/3)
- No long term storage in agricultural area or over a water source. (V/3)
- No more radioactive wastes (V/1)
- Eliminate or minimize creation of more waste. (V/1)
- Linkage with and solution of the high level waste of reactors (V/1)
- Environmental Justice (V/1)
- socioeconomics (V/3)
- Consolidation (one location vs. spread all over country) (L/7)
- Redundancy - two sites, not one (V,M)
- Multiple Facilities (V/1)
- Non-reconstitutable: pits should be altered so as not to be easily reassembled into a viable weapon (M)
- Material resistant to mis-use: low attractiveness level as possible. Reactor-grade isotopic content - highly irradiated. (V/2)
- Resistance to recycling & reuse of fissile materials in weapons (V)
- Spread of US fissile material technology to foreign nations (I/9)

Retrievability / Compatibility with Disposition

- Quick disposition - fuel fabrication and burning - eliminates the need for long term storage of weapons materials. (V)
- Long term storage should not preclude the possible future beneficial use. (V/3)
- Does long-term storage option complement the final disposition alternative (preferably the deep-burn reactor). (V)
- Long-term source of Energy (>50 years) (V/2)

- Resource Conservation (Pu / U for future) (V,V/1)
- Retrievability for legitimate civil purposes. (V)
- Should not compromise future civilian use. (M/5)
- Preservation of disposition options. The alternatives should not exclude any final disposition possibilities. (V/3)
- Retrievability for beneficial use. (V/2)
- Storage form should not preclude future use (V/3)
- Retrievability for inspection for storage integrity as well as for possible reprocessing (for Am removal, chemical stability, or reuse). (V/4)
- Pu available for research (L)
- Ability to reverse process in case of hostilities. (L)

Other

- Capability to store all HEU & weapons, assuming no disposition (V)
- How long facility can store materials (1000, 2000 years (V)
- Integration with other NEPA documents to ensure compatibility of decision-making (M)
- Ability to address entire national need (M)
- Facilitates recovery & disposition of existing weapon production scraps & residues (V/4)
- Utilization of existing resources (facilities / staff) (L/8)
- Use of existing facilities at Hanford. (V/1)
- Current Facility Usage (V/3)
- Cost/benefit on a global scale, including 3rd world need for energy/electricity. (V/2)
- Include external costs in cost / benefit analysis. (?)
- Consolidation of defense & energy materials. (M/4)
- Local, regional & state acceptance. (V/1)
- Public awareness - "right to know " in communities where storage will take place - not necessarily "acceptance" as in #7. (V/1)
- Public Involvement (V)
- Public participation in criteria development & ongoing monitoring of facility (V)
- Political viability (beyond #7) (V)
- Cultural, Social impacts (V)
- Regional impacts (V,V)
- Transparency (V/2)
- Inspectable by 2 or 3 different companies. (?)
- Expand "proliferation" to include U.S. (V)
- No reprocessing (V)
- Additional Benefits (M/7)

Reasons for Criteria being Considered Inappropriate

2. Technical Viability

- Exists Today (not a discriminator)
- Why 50 years? Surplus fissile materials half-life is much longer than that.
- 50 years is too short - should be safe for 3000 years.

3. ES&H

- All work must be done safely, therefore should not be an evaluation factor.
- ES&H compliance must be satisfied - not subject to discussion or ranking.
- Exists Today (not a discriminator)

4. Cost Effectiveness

- Since the cost of protecting weapons and weapons-usable materials is very high, (\$Bs/y) - cost of disposal is not an issue since in general it is savings.
- We spared no cost making Pu & HEU - now we should spare no cost in making them as safe as possible.
- Cost effectiveness must be coupled to benefits and resource conservation.
- It is very difficult to discuss cost effectiveness in relation to risks associated to human life.

5. Timeliness

- If stored weapon standard not achieved soon, the game is already lost. With interim storage in place, the timing for long-term storage is irrelevant.
- Urgency is getting weapons material in to safe, secure (interim) storage. A more reasoned and structured program can deal with long-term storage.
- Timeliness is meaningless - our materials are already secure.
- Using existing facilities removes most of the time constraints.

6. Influence on Russia

- Other nations appear to have different policies than the U.S. We should spend more time evaluating if their proposed actions are better.

7. Public and Institutional Acceptance

- The public is incapable of making valid judgments on highly technical matters. Emotion & often hysteria govern.
- Public will always be divided and likely would not choose best option in any event, e.g., Yucca Mountain.
- The public has proven itself incapable of evaluating nuclear alternatives. Seems to be dominated by "antinuke" radicals.
- Public acceptance is needed for implementation of policy. DOE should find sound policy and explain to the public the facts and reasoning behind it. Guessing what the public wants is questionable.
- General public acceptance requirement may hamper a timely and/or practical program.

Comments Regarding Alternatives

Storage is unnecessary, theft no longer a concern if material is deposited on Venus (800°) or Jupiter (many g-forces).

Consider storing in old mines 1500 to 1700 ft. deep.

Realistically consider other government facilities for storage.

Is the NORAD Tunnel available?

Antarctica or widely separated ocean island should be considered as site.

The PEIS should evaluate the long term storage of fissile material at Rocky Flats. There is already a lot of stuff at Rocky, and if you don't get consensus on another storage site (which is likely), at least the alternative of leaving material at Rocky Flats would already be analyzed.

Consider using DoD bases for storage of pits.

Should use the Hanford 221 canyon building for storage.

Conversion to Low Level Waste via accelerated aging [sic].

Comments Regarding Scope

Consider the option of storing the Russian plutonium.

All Pu from power reactors, whether separated or not, must receive the same treatment as that provided for weapons.

Pretreatment of materials to achieve long term storage criteria must be added (cost, schedule, technical viability to transform materials to meet criteria). Material processing must be addressed — it is the major driver on decisions.

Pretreatment of material, its storage form, and its packaging are equally important, and should be added to PEIS scope.

Packaging is the key problem, and that solution makes the storage locale easily secured.

Form of material in storage should be considered. Pits should be altered so as not to be easily reassembled into a viable weapon.

There should be an emphasis on the final Pu form for long term storage.

Do not totally exclude Pu-238 / explain reasons for exclusion

Should not store long term - should recycle and reuse.

Storage should be temporary until material is fashioned into reactor fuel.

Productive use of the material (burning as fuel) will be cost effective in the long term. Storage is temporary.

Long term storage is a bit premature, with the evolution and quickening pace of emerging technologies.

Solution of the weapons-usable fissile materials absent the solution to the high level waste problem is not a solution.

Other Comments

Influence on Russia

- If it's important to influence Russia, great urgency is needed to prevent diversion in Russia.
- We are too rich to serve as a role model for the rest of the world.
- Influence on Russia is a desired result, not a criterion.
- Russia and other country's inspections not really necessary.
- Influence on others has to be based on a consistent policy. RERTR & domestic spent fuel disposition are examples of our lack of reliability.
- There is absolutely no cooperation among nations. Need to add strengths to solve problem.
- Influence on Russia and Others should include an exchange of ideas and/or solutions

Disposition

- Conversion to spent fuel standard levels seems to be throwing away very costly commodities which have better uses — energy, for one.
- More effort should be devoted to peaceful uses for these materials.
- Fissile materials are a valuable resource and an unacceptable waste, and must (eventually) be beneficially used and consumed.
- Long term storage should be designed to support the deep burn reactor concept for the disposition alternative.
- Store - until better technology is available.
- Consider safe storage as the #1 priority. Do not proceed with processing until a safer technology is developed.

ES&H

- Some criteria are redundant — a technically viable facility is ES&H compliant.
- No mention is made of a long-term plan to deal with the material if the storage facility starts to deteriorate.
- ES&H should be credible and balanced. Risk assessment should be reasonable. I fear safety criteria that require "always," "never," and "guarantee." This directly impacts public acceptance.
- ES&H standards should be rational, supported by scientific basis.
- We do not want storage, processing, nor reprocessing in agricultural area with limited water supply.
- There is not enough water available for nuclear reactors or reprocessing.
- There is no point in asking people to prioritize among required attributes like ES&H
- Excess Pu should be declared a waste and isolated from the environment.
- Research to stabilize the HEU and Pu before temporary and permanent storage - mid and long term goal.
- Remove triggers before long term storage.
- Pu stored in a different state than HEU.

Timeliness

- Long-term storage should be implemented in an urgent manner.
- Time is of the essence.

Public Involvement

- Public & Institutional acceptance is too broad. "Institutional" should override "public" if the technical facts support the decision.
- The DOE should speak up and correct the activists each time they make an improbable statement.
- 6&7 are desirable, but some limits must be established to avoid endless peripheral views and debate.
- Will never get everyone to agree on a workable plan. Some official will have to make the decisions as to when, where, and how. These are not consensus decisions.
- Too much time & compromise should not be spent to achieve consensus among the general public if that unduly and adversely effects the attainment of the very important objectives.
- Public needs to be educated about radiation. They fear it because they don't understand it.
- Need to develop innovative means of risk assessment / communication with the public.
- Listen to all ages, cultures, religions, and organizations, it effects everyone.
- Involve the HAZ-MAT Team from the Pueblos.

Other

- Criteria cannot, should not be ranked at the screening stage.
- It seems inappropriate and impossible to rank order the criteria.
- ES&H risks can be accepted if we must; if we have to pay, we must. Criteria 1, 2, 6, and 7 are show stoppers. The rest are "nice to have."
- Long Term is unfortunate terminology.
- DOE should make effort to financially benefit the locales where work will be done.
- Please don't let the scientists and industrialists be the only input. Health and safety and environmental factors must have the priority.
- If placed in the hands of private contractors, absolute oversight and audit by civilian and military agencies, including Congress.
- Fort Knox has never been robbed; why is theft such a big problem?
- 50-year storage is not sufficient given the half-life of plutonium. It's dishonest to predict some techno fix in 50 years.
- 50 year storage is a bit absurd in light of the half-life of materials.
- Texas does not want this long term storage.
- If we don't bring the process under control we will bankrupt the nation with no useful output.
- Maybe someone needs to offer the President justification for postponing certain knee-jerk reactions by DOE.
- Items are written with an inherent bias (i.e., #3 hinting at over-regulation).
- DOE representatives said that these survey results would not be used as numerical poll result that might influence decision-making.

A.4 DISPOSITION SCREENING CRITERIA QUESTIONNAIRE

Storage & Disposition of Weapons-Usable Fissile Materials <i>Questionnaire</i>
<p><i>Screening Criteria for Determining Reasonable Alternatives for <u>Disposition</u> of Surplus Fissile Materials</i></p> <p>In Fall 1994 the Department of Energy will determine which alternatives for disposition of surplus weapons-usable fissile materials (primarily plutonium and highly-enriched uranium) will be included in a detailed decision process involving a Programmatic Environmental Impact Statement (PEIS) as described in the Notice of Intent (NOI) published in the Federal Register on June 21, 1994.</p> <p>Building on the recent National Academy of Sciences (NAS) study (<u>Management and Disposition of Excess Weapons Plutonium</u>, January 1994), a screening process will be used to rule out unreasonable alternatives, based on the criteria outlined in this questionnaire. Stakeholder and public comments on the screening criteria are invited via return mail. A summary of the input received and the results of the screening process will be published in the PEIS Implementation Plan in early 1995.</p> <p>Disposition alternatives considered in the screening process will include alternatives identified in the NAS report, alternatives summarized in the NOI, and any other alternatives identified in the PEIS scoping process. Each alternative will be evaluated against each of the criteria (modified or refined based on input received).</p> <p>An alternative will be considered to be unreasonable for further evaluation if it is unacceptable in any of the criteria, or ranks so low overall compared to other alternatives that it does not merit further detailed evaluation.</p>	
<p>U.S. Department of Energy, Surplus Fissile Materials Project, 1000 Independence Ave., SW, Washington, D.C. 20585</p>	

Questionnaire

Regarding Criteria for Screening Disposition Alternatives

Disposition is a process of use or disposal of materials that results in the remaining material being converted to a form that is substantially and inherently more proliferation-resistant than the original form.

Nine criteria are proposed for determining reasonable disposition alternatives for surplus weapons-usable fissile materials. Please indicate your views on the *relative* importance of each of the proposed criteria by marking the appropriate box, and also rank the criteria in order of importance (1-9, with 1 being most important) in the spaces provided.

	Very Important	Moderately Important	Less Important	Inappropriate or Unnecessary	Rank Order
1. <u>Resistance to Theft or Diversion in Processing and Storage:</u> Each step in the disposition process must be capable of providing for comprehensive protection and control of weapons-usable fissile material.	☐	☐	☐	☐	_____
2. <u>Resistance to Retrieval, Extraction, and Reuse:</u> The final disposition of the surplus material must be highly resistant to potential reuse in weapons.	☐	☐	☐	☐	_____
3. <u>Technical Viability:</u> There should be a high degree of confidence that the alternative will be technically successful.	☐	☐	☐	☐	_____
4. <u>Environmental, Safety & Health Compliance:</u> High standards of public and worker health and safety, and environmental protection must be met, and significant additional ES&H burdens should not be created.	☐	☐	☐	☐	_____
5. <u>Cost Effectiveness:</u> Disposition should be accomplished in a cost-effective manner, and be compatible with reasonable long term storage alternatives.	☐	☐	☐	☐	_____
6. <u>Timeliness:</u> The technology concept should be demonstrated within ~ 20 years and disposition should be completed within ~ 50 years.	☐	☐	☐	☐	_____
7. <u>Influence on Russia and Other Countries:</u> Each step in the disposition process must allow international inspections, and the alternative should provide a good example for the disposition of international weapons-usable materials inventories.	☐	☐	☐	☐	_____
8. <u>Public and Institutional Acceptance:</u> An alternative should be able to muster a broad and sustainable consensus on the manner in which disposition is accomplished.	☐	☐	☐	☐	_____
9. <u>Additional Benefits:</u> An alternative should leverage government investments for disposition of surplus materials to contribute to other national or international initiatives (such as advancing nuclear reactor technology or producing medical isotopes).	☐	☐	☐	☐	_____

Are there any additional criteria that should be used to evaluate potential disposition alternatives?
(Please include brief definition and rate using the same scheme as above)

	☐	☐	☐	☐	_____
	☐	☐	☐	☐	_____

If any of the criteria are viewed as inappropriate or unnecessary, please provide a brief explanation:

Additional Comments:

(Optional)

Name _____

Affiliation _____

Address _____

Phone _____

Please fold & staple and mail by October 17, 1994 to assure your input is included (no postage necessary)

Relative Importance:	Theft / Diversion	Retrieval / Reuse	Technical Viability	ES&H	Cost	Time	Internat'l Influence	Public / Institutional	Additional Benefits
Very Important	124	76	104	101	35	54	57	42	49
Moderate	15	33	38	34	60	49	47	58	39
Less Important	7	23	2	10	42	32	36	40	40
Inappropriate	1	15	0	1	9	10	5	5	16

Disposition Criteria Importance Ratings

(150 Questionnaires Returned)

Rank:	Theft / Diversion	Retrieval / Reuse	Technical Viability	ES&H	Cost	Time	Internat'l Influence	Public / Institut'l	Additional Benefits		
1	34	12	12	29	3	7	8	7	8		
2	33	14	20	22	7	8	5	7	2		
3	21	22	27	16	8	6	3	5	9		
4	10	9	27	23	8	13	16	7	5		
5	10	9	20	7	16	16	11	12	17		
6	3	16	5	10	22	15	19	16	11		
7	6	11	5	9	14	23	21	23	5		
8	2	9	2	3	21	19	18	27	17		
9	0	15	0	1	18	11	17	15	41		

Disposition Criteria Rankings

(150 Questionnaires Returned)

Comments from Disposition Questionnaire

Additional Criteria that Should be Used

Notations in parentheses: (Relative Importance [V, M, L] / Rank Order [1-9])
(multiple entries reflect multiple inputs)

International

- Transparency should be a separate criteria. (M, V/3)
- International Acceptance (other countries willingness to apply U.S. solution). (V/4)
- Consistency with international effort to provide U.S. leadership and acceptable policies. (V)
- Influence on U.S. alternatives from international choices & plans (M)
- Consistency with NPT allies, trading partners, and Russian nuclear material management plans (M)
- Global common solutions (?)

ES&H

- Low population density. (V/1)
- Transportation Risks (V/6)
- Safety in transportation (V)
- Minimization of fissile material transport and handling. (M)
- Avoidance or delay of criticality in repository. (V/1)
- Geologic stability for disposal. (V)
- Utilization of existing resources [\$\$ impacts also]. (L)
- Safety of present form vs. after use as nuclear fuel. (V)
- Safety of using fuel vs. mining accidents & destruction of natural resources. (V)
- Methods to dispose / reduce waste volumes. (V)
- The amount of waste to be produced should be minimized. (V/6)
- Change in hazard value of material. (M)
- Water resource conservation in Texas (V)
- Buffer zone (V/2)
- Monitorable by independent citizen groups to ensure safety (?)
- Disposition should be final with no bad side effects. (M)
- Reduction in total volume of material stored for long term (?)
- Environmental justice (?)
- Socioeconomic impacts (V/3)
- Accident scenario (?)

Safeguards, Security and Nonproliferation

- High safeguards and security (V/1)
- Prevention of proliferation of nuclear weapons technology (M)
- Resistance to dispersal by high & nuclear explosives by adversary or terrorist. (V/1)
- No Pu mines - destruction of Pu rather than burial (V/2)
- Final content must be highly resistant to potential misuse as weapons - Pu has been removed & fissioned to maximum extent possible. (?/1)
- Provides credible U.S. international leadership in safeguards/security technology (M)

Energy Policy

- Ability to recover energy value, mitigate future energy crisis/compensate for geopolitical influences. (M/4)
- Preserve civil use potential. (V/4)
- Appropriate use of a national asset as an energy resource (V)
- Reuse, rather than merely waste storage and/or disposition. (V)
- Long-term energy needs of our country & global warming. (V/1)
- Using as energy source to conserve fossil resources & reduce air pollution (like France). (V/2)
- Synergism with commercial reactor fuel cycle activities. (M)
- Linkage with and solution of the high-level waste from reactors is very important (V)
- Source of energy for future generations. (V/2)
- Conservation of resources (Pu/U), impact on oil, gas, etc. (V/3)
- Value as fuel fully realized (M/2)
- Potential for energy production as burnable fuel (V/2)
- Economic value to rate-payer/consumer (L)

Misc.

- Include site-specific criteria to enhance public acceptance and timeliness (V)
- Beneficial use of sunk investment (V/3)
- Maximize economic benefit by totally burning (deep burn/recycle) (V/4)
- Include benefits not emphasized (or peaceful uses). (V/1)
- A priority that the final disposition be reuse of material for medical research and like technologies (V/1)
- Direct benefits to Public & National Economy (V/4)
- For additional benefits, include producing energy and lowering electric utility rates. (?)
- Cost/benefit should include consideration of energy & electricity needs of the world, long range. (V/4)
- Flexibility: Ability to reverse program if need arises. (L/10)
- Tritium production with LWR technology. (V/1)
- Facilitates recovery & disposition of existing weapon production scraps & residues (V/3)
- All plutonium from power reactors, whether separated or not, must receive the same treatment as that from weapons (V/2)
- Public Involvement (V)
- Political viability (beyond #8) - can political leaders support & lead (V)
- Put in place quickly. (V/5)
- Positive impacts to future society (V)

Reasons Criteria are Inappropriate

Consolidation / Redundancy

- Criteria 1,2, & 4 can be combined - go / no go considerations
- Criteria 3 & 6 can be combined - they are interrelated.
- Cost effectiveness must be coupled with benefit analysis & conservation of resources.

1. Resistance to Theft or Diversion in Processing and Storage

- Important, but adherence to NAS stored weapons standard is inappropriate.

2. Resistance to Retrieval, Extraction, and Reuse

- Should not poison or dispose of materials that are resources of potential value to future generations.
- Reuse, extraction and retrieval may be an advantage or desirable feature.
- Should keep Pu as an available resource
- Resistance to reuse is a negative attribute.
- Final disposition should not be disposal. It should include burning the radio nuclides for beneficial purposes such as energy generation.
- All strategies being considered seriously can be reversed relatively easily to obtain Pu suitable for weapons, therefore #2 inappropriate.
- National reversal is straight-forward; what is needed is built-in visibility and time delays.
- Theft/diversion covers sub-national/terrorists -- #2 would only stymie U.S. weapons production. Such issues of national security should not be decided via this PEIS.
- No one will want to retrieve for weapons (we know we don't need 10's of thousands). Retrieval for future energy use is a positive attribute.
- Important, but somewhat higher risk than long-term storage is acceptable.

4. ES&H

- Not subject to discussion - must be satisfied to fullest extent possible.
- All work must be done safely - should not be a criterion for evaluation.

5. Cost Effectiveness

- In light of the \$B's per year to store & protect weapons and weapons usable materials offset by disposition, cost for disposition shouldn't be a factor.
- We must safely dispose at any cost, just as we spared no expense to produce them.
- As idealistic as it sounds, cost involved is not an area we should worry about. We need to deal with these materials safely and quickly — spare no expense! Corners cut today are tremendous burdens for the future.
- It is extremely difficult to put a cost on the risks associated to human life.
- Unnecessary if we burn plutonium.

6. Timeliness

- Times given are inappropriate given urgent issues in Russia
- 20 to 50 years is much too long a time period.
- Should be demonstrated now! Revise criterion.
- 20 to 50 years?! Why not 2 to 5 years?
- Should be completed in 20-30 years, not just demonstrated.
- The timing should occur more quickly, with effort placed on using existing, easily modified technology now available in the U.S.
- Periods stated are too long. Problem resolution shouldn't wait 20 years.
- 20 to 50 year time for disposition is too long.

- Technologies should be demonstrated sooner than 20 years.
- No need to complete disposition in 20 - 50 years. Technical / economic options could be available after 50 years.
- Unnecessary if we burn plutonium.
- Time scale is less important than sound policy.

7. Influence on Russia and Other Countries

- Other countries will be more impressed with cost-effective, technically sound solutions.
- Doubtful effectiveness, tenuous connection (like RERTR)
- Setting the example is not the prime goal. Discussions should be based on U.S. interests and goals, and not based on attempts to influence others by example.

8. Public and Institutional Acceptance

- Public has shown that it is incapable of making sensible decisions on highly technical matters. Driven by scare-mongering when it comes to nuclear power reactors.
- Public cannot decide such issues. They must rely on experts.
- This issue is highly debatable, based on emotions. Competent leadership is needed, driven by safety & technology.
- Public & Institutional Acceptance must be gained by DOE. Policy decisions must be based on sound science and real non-proliferation, environmental and energy reasoning. The idea that DOE can predict what the public would accept is naive. No agency should base policy on what people think the public might think.
- Broad public consensus is difficult and inappropriate for this highly-technical, multi-issue program.
- Experts can't talk on my level - wasn't educated to a level to begin to ask questions.

9. Additional Benefits

- "Additional Benefits" encourages the production of more waste.
- Skews choice by introducing irrelevant criterion.
- Side benefits may occur, but this should not be a criterion.
- The priority should be safe disposition of fissile material. Any "additional benefits" should be incidental and not a priority or criteria.
- The problem of safe disposition is orders of magnitude more critical than any possible benefits of "fallout."
- There should be no linkage between weapons material and other programs. Nuclear reactors should be shut down and medical isotopes are enough already.
- It is inappropriate to link the solution of this problem to the goal of advancing nuclear technology or producing medical isotopes. If these become important goals they can be pursued independently from the solution to the problem of nuclear waste and weapons-usable fissile materials.
- This is not a jobs, economic development, or nuclear promotion project. Keep your eye on the ball - the goal is to dispose of these materials in a manner which makes the world safer.

Additional Comments

Alternatives

- DOE should not preclude evaluation of use of all surplus materials in a fuel cycle, either domestic or in allies' systems (environmentally best option).
- Recycle technologies must be evaluated.
- Fort Knox has worked for years — why not build an adjacent fissile material repository? (security with retrievability)
- Include alternatives that use HEU/Pu and allow recovery & reuse where economic. The U.S. should not give up viable alternatives to "set a good example" that the world is not following.
- Technologies viable and cost effective after 50 years from today.

International

- Not sure we can influence other nations when we do not value excess Pu and they do.
- Good example is one that will be followed. The rest of the world is not rich enough to throw away plutonium.
- Important and urgent to value the HEU and Pu in Russia and use these materials.
- Influence on Russia & others should include an exchange of ideas and/or solutions.
- Disposition of Russian Pu is the most pressing problem. Set up a joint contractor to help solve.
- HEU and Pu (pits) are adequately controlled in the U.S. today. We could continue this indefinitely. The issue is Russia and other states of the FSU. Does it make any sense for the U.S. to make this journey alone? If Russia won't reciprocate, what difference does it make to go beyond storage?
- The U.S. should consider what other nations are doing - i.e., burning Pu in reactors for energy value. Maybe the current administration has an incorrect policy.
- The alternatives should consider the impact on other weapon states, not just Russia.
- Stop worrying about Russians. What about \$ value of U.S. HEU and Pu?

Nonproliferation, Safeguards & Security

- Would rather have safe utilization than guarding burial for 100,000 years.
- Technology for burning HEU & Pu is available. Most proliferation-resistant recycle technology exists - IFR.
- U-235 and Pu should be burned in power reactors, the remaining Pu recycled to make new fuel. Full recycling should be done in one location (this makes criterion 1 easy). The recycling of fuel makes the waste product highly resistant to use in weapons.
- Ensure IAEA inspectability.
- Criterion #2 is weak - should state "provide highest degree of inherent resistance" to be consistent with objectives.
- Should pursue "ultimate disposition" not just "disposition" in 50 years.
- The spent fuel standard is not an adequate criterion for Pu disposition. Need to go beyond the spent fuel standard using currently available advanced technologies.

ES&H

- Be careful — high ES&H standards does not mean impossible standards. Public must learn about risk assessment.
- ES&H requirements should be rational and based on legitimate science.
- Environmental costs must be included in cost analysis.
- Don't want storage or processing at Pantex — over major water source.
- Government should declare Pu as a waste and concentrate on isolating it from the environment.

Energy Policy

- Material should be treated as an asset, not liability.
- Additional benefits should include power generation.
- The U.S. needs to revisit energy policy and role of Pu — we rely too much on the stability of the Middle East.
- Since we have this material, it might be good to actually use it for non-military purposes.
- The hundreds of billions of dollars spent have the potential to be springboard for new technology, national security by replacing imported oil.
- Additional benefits should include reducing dependence on foreign oil.
- Save the material as a crucial resource for energy for future generations.
- We recycle everything - why not spent fuel?
- Fissile materials are a valuable resource and an unacceptable waste, and must eventually be beneficially used and consumed.
- It would be unconscionable not to burn this Pu in power reactors.
- Fission research is not a viable choice for "Additional Benefits."

Timeliness

- This PEIS process is taking too long.
- Plutonium reactor technology should be demonstrated within 5 years.
- If the threat of theft and diversion is so great, then timeliness of action is critical. There are technologies currently available to dispose of Pu, however politics are overriding the technical aspects.
- We must do the best possible with all the facts looked at — but do something & cut down the wasted time.
- 20 to 50 years should be changed to ASAP.
- Timeliness periods must be greatly hastened.
- DOE needs to demonstrate Pu burning technology immediately, in parallel with PEIS due to national security at stake.
- Time is of the essence.
- We can afford to wait for further evolution of civil reactor fuel cycle.
- An alternative not viable now could be in 50 years. To this extent, the NAS study is short-sighted.
- Timeliness is important, but we should not rush into something we may regret. If there is no clear "best" option, maybe we shouldn't do anything drastic by pushing an option before the proper time.
- Immediate action on deciding the final disposition may be premature. Store the materials and let the technology catch up.

Technical Viability

- DOE speaks of technology as "available" when it is only at the research stage. Technical viability should rely on existing/present technology and capability rather than relying on "available" technology.
- Technical viability must be judged by unbiased scientists.

- Ensure technical viability with government/industry partnership, utilize DOE & industrial resources efficiently.

Public Involvement / Consensus

- Educate the public.
- Public education is important for participation in dialogue.
- Need ongoing and permanent public comment line - phone & fax.
- Have you considered a check-off box on tax forms asking taxpayer what they want done with their share of the surplus Pu?
- DOE needs "Teller of Tales" to make complex issues understandable.
- Don't know if you'll get public acceptance. DOE should have the backbone to chose the best alternative and implement it anyway.
- Technical ability exists - we need national consensus & support of Congress and public.

Misc.

- Issues of moral and ethical responsibility more important than technology.
- Materials should not advance nuclear technology - reactors must be shut down if on surface.
- Criteria 1,2,3,7,& 8 are show stoppers (but consensus doesn't mean unanimity). Other criteria are "nice to have."
- Don't rank-order the criteria at the screening stage.
- It seems inappropriate and impossible to rank-order the criteria.
- It is very hard to give an absolute order of priority, since all the factors need to be considered as part of a systems answer.
- No material should be dispositioned - too much economic, energy, and national security uncertainties.
- It appears that the criteria are oriented towards the burial option primarily (e.g., #2) and do not consider other options.
- Please don't let private industry get control of this task. We need international control, co-option and watchdogging.
- Noted bias in manner that statements are worded.
- One questionnaire for both storage and disposition may have been possible. Would save 50% of the cost.
- Not convinced this program needs an EIS process.

APPENDIX B

Spread Sheet of Plutonium Disposition Options

The options are organized in the following Sections:

- Storage (Section S)
- Direct Disposal (Section D)
- Immobilization with Radionuclides (Section I)
- Reactor and Accelerator (Section R)

Steps needed to address all possible source forms are included:

- Processing¹
- Feed Preparation
- Denaturing
- Prep for Final Disposal
- Ultimate Disposition

The last column of the spread sheet indicates whether or not the option was either addressed in the NAS study and/or specifically identified in the NOI.

¹Some of the processing identified may be done to meet interim or long term storage requirements, and therefore would not be included in the analysis of disposition actions.

CONSOLIDATED OPTIONS FOR EXCESS PU DISPOSITION

#	SOURCE FORM	PROCESSING	FEED PREPARATION	DENATURING	PREP FOR FINAL DISPOSITION	ULTIMATE DISPOSITION	NAS/NOI OPTION
STORAGE OPTIONS (Section S)							
S1 NO PLUTONIUM DISPOSITION ACTION							
	PITS	NONE	NONE	NONE	PACKAGING FOR CONTINUED STORAGE	LONG TERM STORAGE FACILITY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	NONE	• •	• •	• •	• •	
	UNIRRADIATED FUEL	NONE	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE PU RECOVERY OR WASTE	• •	• •	• •	• •	
S2 RADIATION BARRIER ALLOY (STORAGE)							
	PITS	PU RECOVERY FROM PITS	METAL PRODUCTION	ALLOY WITH BE	ARRAY ASSEMBLY	STORAGE FACILITY	NO
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	PU RECOVERY FROM RESIDUES	• •	• •	• •	• •	
	UNIRRADIATED FUEL	PU RECOVERY FROM FUEL FORM	• •	• •	• •	• •	
	LEAN RESIDUES	PU RECOVERY FROM LEAN RESIDUES	• •	• •	• •	• •	
DIRECT DISPOSAL OPTIONS (SECTION D)							
D1 DIRECT EMPLACEMENT IN HLW REPOSITORY							
	PITS	PU RECOVERY FROM PITS	NONE	NONE	PROCESSING TO FINAL DISPOSAL FORM	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	• •	• •	• •	• •	• •	
	UNIRRADIATED FUEL	• •	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	• •	• •	• •	• •	
D2 IMMOBILIZATION WITHOUT RADIONUCLIDES TO DEEP BOREHOLE							
	PITS	PU RECOVERY FROM PITS	NONE	NONE	IMMOBILIZATION W/O RADIONUCLIDES	DEEP BOREHOLE	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	• •	• •	• •	• •	• •	
	UNIRRADIATED FUEL	PU RECOVERY	• •	• •	• •	• •	
	LEAN RESIDUES	• •	• •	• •	• •	• •	
D3 DIRECT DISCARD TO DEEP BOREHOLE							
	PITS	PU RECOVERY FROM PITS	NONE	NONE	CANISTER LOADING	DEEP BOREHOLE	POSSIBLY
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	• •	• •	• •	• •	• •	
	UNIRRADIATED FUEL	PU RECOVERY	• •	• •	• •	• •	
	LEAN RESIDUES	• •	• •	• •	• •	• •	
D4 DISCARD TO WIPP							
	PITS	PU RECOVERY FROM PITS	NONE	NONE	PROCESSING TO WIPP SPECIFICATIONS	WIPP-LIKE TRU REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	• •	• •	• •	• •	• •	
	UNIRRADIATED FUEL	• •	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	• •	• •	• •	• •	

CONSOLIDATED OPTIONS FOR EXCESS PU DISPOSITION

#	SOURCE FORM	PROCESSING	FEED PREPARATION	DENATURING	PREP FOR FINAL DISPOSITION	ULTIMATE DISPOSITION	NAS/NOI OPTION
D5 HYDRAULIC FRACTURING							
	PITS	PU RECOVERY FROM PITS	DISSOLUTION	NONE	PROCESSING TO FINAL DISPOSITION FORM	SHALE FORMATION	NO
	CLEAN OXIDE/METAL	NONE	. .	. .	. .	. .	
	RICH RESIDUES	NONE	. .	. .	. .	. .	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	. .	. .	. .	. .	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	. .	. .	. .	. .	
D6 DEEP WELL INJECTION							
	PITS	PU RECOVERY FROM PITS	DISSOLUTION	NONE	PROCESSING TO FINAL DISPOSITION FORM	SEDIMENTARY FORMATION	NO
	CLEAN OXIDE/METAL	NONE	. .	. .	. .	. .	
	RICH RESIDUES	NONE	. .	. .	. .	. .	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	. .	. .	. .	. .	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	. .	. .	. .	. .	
D7 INJECTION INTO CONTINENTAL MAGMA							
	PITS	PU RECOVERY FROM PITS	NONE	NONE	PROCESSING TO FINAL DISPOSITION FORM	CONTINENTAL MAGMA BODY	NO
	CLEAN OXIDE/METAL	NONE	. .	. .	. .	. .	
	RICH RESIDUES	NONE	. .	. .	. .	. .	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	. .	. .	. .	. .	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	. .	. .	. .	. .	
D8 MELTING IN CRYSTALLINE ROCK							
	PITS	PU RECOVERY FROM PITS	NONE	NONE	PROCESSING TO FINAL DISPOSITION FORM	CONTINENTAL BEDROCK	NO
	CLEAN OXIDE/METAL	NONE	. .	. .	. .	. .	
	RICH RESIDUES	NONE	. .	. .	. .	. .	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	. .	. .	. .	. .	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	. .	. .	. .	. .	
D9 DISPOSAL UNDER ICE CAPS							
	PITS	PU RECOVERY FROM PITS	NONE	NONE	PROCESSING TO FINAL DISPOSITION FORM	ANTARCTIC ICE CAP	NO
	CLEAN OXIDE/METAL	NONE	. .	. .	. .	. .	
	RICH RESIDUES	NONE	. .	. .	. .	. .	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	. .	. .	. .	. .	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	. .	. .	. .	. .	
D10 SEABED (PLACEMENT ON OCEAN FLOOR)							
	PITS	PU RECOVERY FROM PITS	NONE	NONE	PROCESSING TO FINAL DISPOSITION FORM	SEABED	NO
	CLEAN OXIDE/METAL	NONE	. .	. .	. .	. .	
	RICH RESIDUES	NONE	. .	. .	. .	. .	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	. .	. .	. .	. .	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	. .	. .	. .	. .	
D11 SUB SEABED EMPLACEMENT							
	PITS	PU RECOVERY FROM PITS	NONE	NONE	PROCESSING TO FINAL DISPOSITION FORM	SUB SEABED	YES
	CLEAN OXIDE/METAL	NONE	. .	. .	. .	. .	
	RICH RESIDUES	NONE	. .	. .	. .	. .	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	. .	. .	. .	. .	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	. .	. .	. .	. .	

CONSOLIDATED OPTIONS FOR EXCESS PU DISPOSITION

#	SOURCE FORM	PROCESSING	FEED PREPARATION	DENATURING	PREP FOR FINAL DISPOSITION	ULTIMATE DISPOSITION	NAS/NOI OPTION
D 12 OCEAN DILUTION							
	PITS	PU RECOVERY FROM PITS	DISSOLUTION	NONE	PROCESSING TO FINAL DISPOSITION FORM	SEA DILUTION	YES
	CLEAN OXIDE/METAL	NONE	.	.	.	.	
	RICH RESIDUES	.	.	.	.	.	
	UNIRRADIATED FUEL	.	.	.	.	.	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	.	.	.	.	
D 13 DEEP SPACE LAUNCH							
	PITS	PU RECOVERY FROM PITS	NONE	NONE	SPACE FORM PROCESSING / LAUNCH	DEEP SPACE	YES
	CLEAN OXIDE/METAL	NONE	.	.	.	.	
	RICH RESIDUES	.	.	.	.	.	
	UNIRRADIATED FUEL	.	.	.	.	.	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	.	.	.	.	
IMMOBILIZATION WITH RADIONUCLIDES (SECTION I)							
I 1 UNDERGROUND NUCLEAR DETONATION							
	PITS	NONE	PACKAGING AND EMPLACEMENT	UNDERGROUND DETONATION	NONE	NTS UNDERGROUND CAVITY	YES
	CLEAN OXIDE/METAL	.	.	.	.	.	
	RICH RESIDUES	.	.	.	.	.	
	UNIRRADIATED FUEL	.	.	.	.	.	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	.	.	.	.	
I 2 BOROSILICATE GLASS IMMOBILIZATION W/RADIONUCLIDES AT DWPF, THEN TO HLW REPOSITORY							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE	GLASS IMMOB W/RADIONUCLIDES	CANISTER PACKAGING	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	.	.	.	.	
	RICH RESIDUES	NONE	.	.	.	.	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	.	.	.	.	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	.	.	.	.	
I 3 BOROSILICATE GLASS IMMOBILIZATION W/RADIONUCLIDES AT A NEW FACILITY, THEN TO HLW REPOSITORY							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE	GLASS IMMOB W/RADIONUCLIDES	CANISTER PACKAGING	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	.	.	.	.	
	RICH RESIDUES	NONE	.	.	.	.	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	.	.	.	.	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	.	.	.	.	
I 4 CERAMIC IMMOBILIZATION W/RADIONUCLIDES, THEN TO HLW REPOSITORY							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE	GLASS IMMOB W/RADIONUCLIDES	CANISTER PACKAGING	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	.	.	.	.	
	RICH RESIDUES	NONE	.	.	.	.	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	.	.	.	.	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	.	.	.	.	
I 5 ELECTROMETALLURGICAL TREATMENT W/RADIONUCLIDES, THEN TO HLW REPOSITORY							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO METAL	METAL IMMOB W/RADIONUCLIDES	CANISTER PACKAGING	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	.	.	.	.	
	RICH RESIDUES	NONE	.	.	.	.	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	.	.	.	.	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	.	.	.	.	

CONSOLIDATED OPTIONS FOR EXCESS PU DISPOSITION

#	SOURCE FORM	PROCESSING	FEED PREPARATION	DENATURING	PREP FOR FINAL DISPOSITION	ULTIMATE DISPOSITION	NAS/NOI OPTION
16	BOROSILICATE GLASS OXIDATION/DISSOLUTION/IMMOBILIZATION W/RADIONUCLIDES, THEN TO HLW REPOSITORY						
	PITS	PU RECOVERY FROM PITS	NONE	OXIDATION/DISSOLUTION/IMMOBILIZATION	CANISTER PACKAGING	US HLW REPOSITORY	NO
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	NONE	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE VOLUME REDUCTION	• •	• •	• •	• •	

REACTOR AND ACCELERATOR OPTIONS (SECTION R)

R1 EURATOM MOX FABRICATION / REACTOR BURNING

PITS	PU RECOVERY FROM PITS	NONE	COMMERCIAL MOX MARKET	FOREIGN SPENT FUEL PROCESSING	FOREIGN HLW REPOSITORY	YES
CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	

R2 EXISTING LIGHT WATER REACTORS

PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, MOX FABRICATION	EXISTING LWR	STORAGE/SPENT FUEL PROCESSING	US HLW REPOSITORY	YES
CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	

R2A PARTIALLY COMPLETED LIGHT WATER REACTORS

PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, MOX FABRICATION	EXISTING LWR	STORAGE/SPENT FUEL PROCESSING	US HLW REPOSITORY	YES
CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	

R3 ADVANCED LIGHT WATER REACTORS

PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, MOX FABRICATION	NEW LWR	STORAGE/SPENT FUEL PROCESSING	US HLW REPOSITORY	YES
CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	

R4 NAVAL PROPULSION REACTORS

PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, FUEL FABRICATION	NAVAL PU REACTORS	STORAGE/SPENT FUEL PROCESSING	US HLW REPOSITORY	YES
CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	

R5 MODULAR HELIUM REACTORS

PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, FUEL FABRICATION	MHR	STORAGE/SPENT FUEL PROCESSING	US HLW REPOSITORY	YES
CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	

CONSOLIDATED OPTIONS FOR EXCESS PU DISPOSITION

#	SOURCE FORM	PROCESSING	FEED PREPARATION	DENATURING	PREP FOR FINAL DISPOSITION	ULTIMATE DISPOSITION	NAS/NOI OPTION
R6 CANDU HEAVY WATER REACTORS							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, FUEL FABRICATION	CANDU REACTOR	STORAGE/SPENT FUEL PROCESSING	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	
R7 ADVANCED LIQUID METAL REACTORS WITH PYROPROCESSING							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO METAL, FUEL FABRICATION	ALMR	STORAGE/SPENT FUEL PYROPROCESSING	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	
R8 ACCELERATOR CONVERSION / MOLTEN SALT TARGET							
	PITS	PU RECOVERY FROM PITS	DISSOLVE IN FLUORONATED SALT	MOLTEN SALT ACCELERATOR BURN	STORAGE/SPENT FUEL PROCESSING	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	NONE	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	
R9 ACCELERATOR CONVERSION / PARTICLE BED TARGET							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, TARGET FABRICATION	PARTICLE BED ACCELERATOR BURN	STORAGE/SPENT FUEL PROCESSING	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	NONE	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	
R10 EXISTING LIGHT WATER REACTORS WITH MOX FUEL REPROCESSING							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, MOX FABRICATION	EXISTING LWR	SPENT FUEL REPROCESSING FOR RECYCLE	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	
R11 ADVANCED LIGHT WATER REACTORS WITH MOX FUEL REPROCESSING							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, MOX FABRICATION	NEW LWR	SPENT FUEL REPROCESSING FOR RECYCLE	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	
R12 ACCELERATOR-DRIVEN MODULAR HELIUM REACTORS							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, FUEL FABRICATION	MHR	ACCELERATOR BURN	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	

CONSOLIDATED OPTIONS FOR EXCESS PU DISPOSITION

#	SOURCE FORM	PROCESSING	FEED PREPARATION	DENATURING	PREP FOR FINAL DISPOSITION	ULTIMATE DISPOSITION	NAS/NOI OPTION
R 13 ADVANCED LIQUID METAL REACTORS WITH PU RECYCLE							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO METAL, FUEL FABRICATION	ALMR	SPENT FUEL REPROCESSING FOR RECYCLE	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	
R 14 PARTICLE BED REACTORS							
	PITS	PU RECOVERY FROM PITS	CONVERSION TO OXIDE, FUEL FABRICATION	PBR	SPENT FUEL REPROCESSING FOR RECYCLE	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	
R 15 MOLTEN SALT REACTORS							
	PITS	PU RECOVERY FROM PITS	DISSOLVE IN FLUORONATED SALT	MSR	SPENT FUEL REPROCESSING FOR RECYCLE	US HLW REPOSITORY	YES
	CLEAN OXIDE/METAL	NONE	• •	• •	• •	• •	
	RICH RESIDUES	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	UNIRRADIATED FUEL	RECOVERY OF CLEAN PU	• •	• •	• •	• •	
	LEAN RESIDUES	ON-SITE RECOVERY OF PU	• •	• •	• •	• •	

APPENDIX C. SCREENING COMMITTEE MEMBERS

The screening process was conducted by a committee of cognizant Department of Energy Officials:

Howard R. Canter, Chair
Technical Director
Office of Fissile Materials Disposition

Greg Rudy
Acting Director
Office of Fissile Materials Disposition

J. David Nulton
Director, NEPA Compliance and Outreach
Office of Fissile Materials Disposition

Andre I. Cygelman
Deputy Technical Director
Office of Fissile Materials Disposition

Patrick T. Rhoads
General Engineer
Office of Fissile Materials Disposition

Dr. Randall M. Erickson, Executive Secretary
Technical Advisor
Office of Fissile Materials Disposition

The screening process was supported by the following Technical Advisors and Support Staff:

Jeffery Kass
Lawrence Livermore National Laboratory

Gordon Michaels
Oak Ridge National Laboratory

Dr. TJ Trapp
Los Alamos National Laboratory

James Wright
Sandia National Laboratories, California

James W. Vaughan
Consultant

John Didlake
Sandia National Laboratories, California

Dr. Booth Myers
Lawrence Livermore National Laboratory