Report to Congress: Disposition of Surplus Defense Plutonium at Savannah River Site

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National Nuclear Security Administration
Office of Fissile Materials Disposition

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Executive Summary

Introduction:

In the National Defense Authorization Act of FY2002, Congress directed the U.S. Department of Energy (DOE) to provide, not later than February 1, 2002, a plan for disposal of surplus defense plutonium currently located at the Savannah River Site (SRS) and to be shipped to the SRS in the future. Congress directed that the plan:

- Review each option considered for such disposal,
- Identify the preferred option,
- State the cost of construction and operation of the facilities required,
- Specify a schedule for construction of such facilities, including milestones,
- Specify a schedule for funding the cost of such facilities, and
- Specify the means by which all such plutonium will be removed from the SRS for storage or disposal elsewhere.

This report is the National Nuclear Security Administration's response to the Congressional directive.

At the request of the Administration, during the first quarter of FY 2002 the Department of Energy (DOE) undertook a review of options to restructure U.S. plutonium disposition cooperation with Russia. Concerns had been expressed by the Administration regarding the cost of both the U.S. and Russian programs, prospects for international funding of the Russian program, and the sustainability of the programs. The purpose of the review was to identify and recommend a more cost effective approach to disposition excess plutonium, one which engages Russian interest and commitment, avoids unnecessarily undercutting existing commitments, either domestic or international, and supports broader U.S. nonproliferation and security objectives.

None of the 34 MT of surplus defense plutonium to be dispositioned under the September 2000 U.S.-Russia Plutonium Management and Disposition Agreement (PMDA) is currently located at the SRS. However, the need to ensure a pathway for disposal of such plutonium to be shipped to SRS in the future was a major consideration in the conduct of the Administration-directed review. The information relative to the U.S. program developed during that review addresses the planning requirements set forth by Congress and has been used in preparation of this report.

Discussion:

During the Administration-directed review, numerous options for U.S. plutonium disposition were evaluated to determine whether they could adequately address the concerns expressed by the Administration. More than 40 approaches were considered with 12 distinct options selected for detailed analysis. Six mixed-oxide (MOX)-based reactor disposition options, two advanced reactor disposition options, and four non-reactor options (immobilization and long-term storage) were analyzed. The costs developed during the review and presented in this report reflect the incremental costs for disposing of surplus plutonium (e.g., facility design, construction, operation, and deactivation) and exclude sunk costs from prior years.

Each option was categorized as "coupled" or "de-coupled" based on whether it is consistent with the intent of the September 2000 U.S.-Russia Plutonium Management and Disposition Agreement, and on whether it is judged that Russia could be persuaded to agree to the option.

Costs and schedules for the U.S. options and the advantages and disadvantages of the options are summarized in Tables ES-1 and ES-2.

Table ES-1. Summary of Costs and Schedules for U.S. Options

Option Grouping	Option	Cost to Implement[a,b] (Billion FY 2001 Constant $)	Irradiation Completion Date	Immobilization Completion Date
Coupled Options				
MOX (6)	1a. Project Baseline – One-Year Delay [in the Start of Construction of the MOX FFF] from Cost Report	5.4	FY 2020	FY 2020
	1b. Project Baseline with Accelerated MOX Throughput	4.6	FY 2016	FY 2020
	2. MOX with 34 MT Pu – All PIP Mat'l Purified at F-Canyon	5.0 [c]	FY 2019	n/a
	3a. MOX Only with High-Quality Pu – Some PIP Mat'l Purified at Enhanced MOX FFF	3.8	FY 2019	n/a
	3b. MOX Only with High-Quality Pu – Some PIP Mat'l Purified at F-Canyon	4.0 [c]	FY 2019	n/a
	4. Eurofab / U.S. Burn	3.3 [d]	FY 2022	n/a
Advanced Reactors (2)	5a. Advanced Reactors – GT-MHR	6.1 [e]	FY 2032	n/a
	5b. Advanced Reactors – Thorium Fuel Cycle	5.4 [f]	FY 2027	n/a
De-Coupled Options				
Immobilization (2)	1a. Immobilize at SRS (13 MT); Store Pits Indefinitely	2.0 [g]	n/a	FY 2023
	1b. Immobilize at SRS (34 MT)	3.2	n/a	FY 2021
Storage (2)	2. Store in Place	4.6 [h]	n/a	n/a
	3. Consolidate / Store at Fewer Sites	3.5 [i]	n/a	n/a

[a] Costs for all options include research and development, pre-capital, design and construction of facilities and capital equipment, operations, deactivation, MOX and HEU fuel credits (where applicable), and contingency. Costs exclude pre-FY 2002 costs and pre-disposition interim storage costs that would be incurred under any of the disposition options.

[b] For all coupled options and de-coupled Option #1b**,** Pit Disassembly and Conversion Facility (PDCF) operating costs include PDCF-specific safeguards and security and pit packaging activities.

[c] For F-Area facilities costs for coupled Options 2 and 3b, operating costs partially cover surveillance and maintenance of F-Canyon but do not cover life-extension upgrades, and deactivation costs are excluded. Sharing of operating costs with other DOE program elements is assumed.

[d] For coupled Option 4, assumptions include: 1) The Plutonium Immobilization Plant (PIP) and MOX Fuel Fabrication Facility (MOX FFF) would be eliminated. 2) The PDCF would convert all pit and non-pit materials to plutonium oxide feed material for fabrication of MOX fuel in a European facility.

[e] For coupled Option 5a, assumptions include: 1) Costs include an optimistic $9 billion in anticipated revenue recovery and residual reactor value. 2) The PIP and MOX FFF would be eliminated. 3) The PDCF would convert all pit and non-pit materials to plutonium oxide feed material. 4) A new fuel fabrication facility would be required. 5) Three new reactor plants including 12 reactor modules would be constructed. 6) Extensive reactor design development, component development and testing, and code development would be required.

[f] For coupled Option 5b, assumptions include: 1) The PIP would be eliminated. 2) The PDCF would convert all pit and non-pit materials to plutonium oxide feed material for the thorium fuel fabrication facility, and the PDCF would perform aqueous polishing. 3) Substantial thorium fuel development and testing would be required. 4) Fuel fabrication process and equipment development would be required. 5) New analytical codes and a more extensive lead (fuel) test assembly program would be required.

[g] For de-coupled Option 1a: 1) The cost does not include an annual storage cost of $26 million to indefinitely store the pit material at Pantex. 2) Because 13 MT of non-pit plutonium currently stored at Rocky Flats, Hanford, SRS, LANL, and LLNL would be immobilized, no incremental costs for storage of this material is included in this option.

[h] For de-coupled Option 2: 1) The cost does not include an annual storage cost of $246 million that would continue to occur after the end of the assumed disposition period (i.e., FY 2027). This cost would continue indefinitely because the plutonium would remain undispositioned in its current form. 2) It is

assumed that no new consolidated storage facility is developed. 3) Facility upgrade costs are included as applicable. 4) This option includes storage costs for Pantex, Rocky Flats, Hanford, SRS, LANL, and LLNL.

[i] For de-coupled Option 3, the cost does not include an annual storage cost of $105 million that would continue to occur after the end of the assumed disposition period (i.e., FY 2027). This cost would continue indefinitely because the plutonium would remain undispositioned in its current form.

Table ES-2. Comparison of U.S. Option Groups

Key ●—More Advantageous ◑—Neutral ○—Less Advantageous	**Cost Range (Billion FY2001 Dollars)**	**Engages Russian Interest & Commitment**	**Domestic Commitments**	**International & Nonproliferation Objectives**
MOX	3.3 – 5.4	●	●	●
Advanced Reactors	5.4 – 6.1	○	○	○
Immobilization	2.0 – 3.2	○	◑	○
Storage	3.5 – 4.6 [a]	○	○	○

[a] Plus long-term storage costs.

MOX Only with High Quality Pu-Some Immobilization Material Purified at Enhanced MOX Fuel Fabrication Facility (Option 3a) is the most advantageous option for disposition of U.S. surplus plutonium and should be pursued as the preferred option. The bases for this conclusion are discussed in detail in this report. Under this option, 32 MT of surplus weapons-grade plutonium would be converted to MOX fuel and irradiated in existing commercial nuclear reactors at 3.5 MT/year. This includes 6.4 MT of impure plutonium, previously intended for immobilization, that would instead be purified using enhanced aqueous polishing in the MOX Fuel Fabrication Facility (MOX FFF) and converted to MOX fuel. The remaining 2 MT of plutonium that is the most difficult and costly to convert into MOX fuel would be directly disposed of as waste. Because material disposed of as waste does not count toward the total of 34 MT to be dispositioned under the U.S.-Russia Plutonium Management and Disposition Agreement, this material would be replaced with 2 MT of surplus plutonium from future surplus declarations, maintaining the total under the agreement at 34 MT. All surplus defense plutonium brought to SRS for disposition under this option will be removed from SRS in the form of fresh MOX fuel assemblies. These fuel assemblies will be irradiated in commercial nuclear reactors, and the spent fuel that is produced will ultimately be disposed of as part of each reactor's spent fuel disposal program.

Consultations will be held with appropriate members of Congress and state and local governments regarding disposal of 2 MT of material as waste. In addition, specific consultations will be held with the State of South Carolina regarding shipment of plutonium into the state under the plutonium disposition program and the environmental impacts associated with plutonium disposition activities at SRS.

This preferred option costs $3.84 billion (constant FY 2001 dollars) to implement over approximately 20 years, distributed as follows: Pit Disassembly and Conversion Facility (PDCF) $1.69 billion and MOX FFF $2.15 billion. The estimated costs to implement the option are shown in Table ES-3. The funding requirements for this preferred option are about $2 billion less than that which would be required for the baseline option described in the March 2001 Cost Report prior to the Administration-directed review. The lower cost is primarily the result of eliminating the Plutonium Immobilization Plant and optimizing the design of the PDCF. Reduced operations costs for the MOX FFF and PDCF due to shortened operating lifetimes and an increase in the MOX fuel credit due to increased MOX throughput also contribute to the lower total cost, but these savings are offset by increases associated with increased MOX FFF throughput.

Table ES-3. Total Projected Cost to Implement Preferred Option by Cost Category: FY 2002 – FY 2020

(thousands of **constant FY 2001** dollars)

Facility Name or Type	Research & Development and Pre-Capital	Design & Construction of Facilities and Equipment Capital	Operations [1]	Deactivation	Contingency	Total
PDCF	249,300	440,900	718,200	9,100	267,700	$1,695,200
MOX FFF	326,800	1,058,200	1,226,800	9,100	497,800	$2,154,500 [2]
TOTAL	**$576,100**	**$1,509,100**	**$1,945,000**	**$18,200**	**$765,500**	**$3,849,700 [2]**

[1] Deactivation is not included in the Operations cost category. For PDCF, operating costs include PDCF-specific safeguards and security and pit packaging activities.

[2] The total Cost to Implement and total MOX FFF cost include MOX (-$733,200) and HEU fuel credits (-$231,000) that are not shown on the table.

The key milestones for implementing this option are listed in Table ES-4.

Table ES-4. Key Milestones

Milestone	Facilities	
	PDCF	**MOX FFF**
Conceptual design/NEPA	n/a	n/a
Design	FY 1999-2004	FY 1999-2003
NRC licensing	n/a	FY 2000–2005
Long-lead equipment procurement & site preparation	FY 2005 - 2006	FY 2003-2004
Construction	FY 2006 - 2009	FY 2004 - 2007
Startup	FY 2009	FY 2007
First MOX fuel fabricated	n/a	FY 2008
Full-scale operations	FY 2010 - 2017	FY 2007 - 2019
Deactivation	FY 2018	FY 2020

Table ES-5 presents the projected annual funding that would be required to implement this plutonium disposition option over its life cycle. These costs are for U.S. plutonium disposition activities only. Costs for other Office of Fissile Materials Disposition activities are not included.

Table ES-5. Estimated Annual Funding Requirements for Preferred U.S. Plutonium Disposition Option: FY 2002– FY 2020

Facility Name	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011-2020	Total
PDCF	37.0	65.3	32.9	37.4	146.0	274.9	268.9	94.7	98.8	639.3	$1,695.2
MOX FFF	115.0	155.5	417.7	447.9	419.1	237.7	55.2	52.2	19.3	234.9	$2,154.5
TOTAL	**$152.0**	**$220.8**	**$450.6**	**$485.3**	**$565.1**	**$512.6**	**$324.1**	**$146.9**	**$118.1**	**$874.2**	**$3,849.7**

MOX technology has been commercially developed and is in use in several countries worldwide. As a result, there is a high degree of confidence in the costs, which are also based on the several years of design and development efforts in the U.S.

Implementation of the preferred U.S. plutonium disposition option will result in removal from the Savannah River Site of all surplus defense plutonium currently planned for disposition. It will facilitate the closure of the Rocky Flats Plant by 2006 and removal of stored plutonium from other sites around the DOE complex. Selection of this option will require some additional NEPA review to substitute an expansion of the MOX program for the immobilization element in the current Project Baseline. This option will also require the addition of two reactors to the four currently under contract.

Total Fissile Materials Disposition Program funding requirements for FY 2002 through FY 2008, including U.S. plutonium disposition, U.S. highly enriched uranium (HEU) disposition, fissile materials storage, and Russian fissile materials disposition, are shown in Table ES-6. These costs have been adjusted for escalation and are presented in current year dollars.

Table ES-6. Estimated Annual Funding Requirements for Fissile Materials Disposition Program: FY 2002– FY 2008

(millions of **current year escalated** dollars)

Program Area	2002 Approp.	2003	2004	2005	2006	2007	2008
U.S. Plutonium Disposition							
PDCF	37.0	65.3	35.7	41.6	166.4	322.7	325.1
MOX FFF	115.0	155.5	451.5	497.6	477.8	279.1	66.7
PIP	3.0	-	-	-	-	-	-
Subtotal: U.S. Plutonium Disposition	**155.0**	**220.8**	**487.2**	**539.2**	**644.2**	**601.8**	**391.8**
HEU Disposition	50.0	105.0	93.0	95.5	108.3	99.8	83.4
Storage/Other	28.1	24.6	32.4	40.0	41.5	38.9	33.2
Subtotal: U.S. Fissile Materials Disposition Program	**233.1**	**350.4**	**612.6**	**674.7**	**794.0**	**740.4**	**508.5**
Russian Fissile Materials Disposition [a]							
Funds Spent in Russia	6.0	20.0	32.4	44.4	45.6	47.0	48.4
Funds Spent in U.S.	13.0	14.0	16.2	22.2	22.8	23.5	24.2
Subtotal: Russian Fissile Materials Disposition Program	**19.0**	**34.0**	**48.6**	**66.7**	**68.4**	**70.4**	**72.5**
FISSILE MATERIALS DISPOSITION PROGRAM TOTAL	**$252.1**	**$384.4**[b]	**$661.2**	**$741.4**	**$862.4**	**$810.9**	**$581.0**

a. Russian materials disposition funding does not include $200 million previously set aside

b. DOE's FY 2003 budget request to Congress is $384.0 million

Conclusions:

Major improvements in the Plutonium Disposition Program resulting from the Administration-directed review are as follows:

- Total cost to implement the U.S. program has been reduced by about $2 billion, relative to the disposition strategy presented in the March 2001 Cost Report, primarily by replacing the immobilization portion of the program with enhanced MOX capability.

- Peak year funding requirements for the program have been reduced by approximately $500 million by constructing the MOX Fuel Fabrication Facility and the Pit Disassembly and Conversion Facility sequentially.

- The overall U.S. disposition program schedule has been reduced by three years by accelerating the rate at which plutonium is processed.

- Cost and schedule uncertainties have been reduced by focusing the disposition effort on technologies that are more proven than those of the previous program.

The review also has resulted in an option that is responsive to concerns regarding closure of the Rocky Flats Plant by 2006 and that ensures a path forward for removal of surplus defense plutonium brought to the Savannah River Site for disposition. DOE believes that these improvements are responsive to the concerns regarding the program that were expressed by the Administration. Implementation of these improvements will form a sound basis for proceeding with disposal of surplus defense plutonium at the SRS under the U.S.-Russia PMDA.

1. Introduction

In the National Defense Authorization Act of FY2002, Congress directed the U.S. Department of Energy (DOE) to provide, not later than February 1, 2002, a plan for disposal of surplus defense plutonium currently located at the Savannah River Site (SRS) and to be shipped to the SRS in the future. Congress directed that the plan:

- Review each option considered for such disposal,
- Identify the preferred option,
- State the cost of construction and operation of the facilities required,
- Specify a schedule for construction of such facilities, including milestones,
- Specify a schedule for funding the cost of such facilities, and
- Specify the means by which all such plutonium will be removed from the SRS for storage or disposal elsewhere.

This report is the National Nuclear Security Administration’s response to the Congressional directive.

During the first quarter of FY2002, at the request of the Administration, the Department of Energy, in cooperation with the Department of State and the Department of Defense, conducted a review of options to restructure the U.S.-Russia cooperative plutonium disposition program. Concerns had been expressed by the Administration regarding the cost of both the U.S. and Russian programs, prospects for international funding of the Russian program, and the sustainability of the programs. The purpose of the review was to identify and recommend a more cost effective approach to disposition excess plutonium, one which engages Russian interest and commitment, avoids unnecessarily undercutting existing commitments, either domestic or international, and supports broader U.S. nonproliferation and security objectives.

None of the 34 MT of surplus defense plutonium to be dispositioned under the September 2000 U.S.-Russia Plutonium Management and Disposition Agreement (PMDA) is currently located at the SRS. However, the need to ensure a pathway for disposal of such plutonium to be shipped to SRS in the future was a major consideration in the conduct of the Administration-directed review. The information relative to the U.S. program developed during that review addresses the planning requirements set forth by Congress and has been used in preparation of this report.

A description of the evolution of the U.S. plutonium disposition program is provided in Chapter 2. Chapter 3 summarizes the methodology used in the Administration-directed review to choose various options to be considered for disposition of U.S. surplus plutonium and to conduct the review of the chosen options. Chapter 4 summarizes the assessment of each option chosen for review. These two chapters provide the information requested by Congress regarding the review of options for disposal. Chapter 5 describes the preferred option for plutonium disposition and provides detailed information on project cost, schedule, and annual funding requirements, as well as a discussion of the means by which surplus defense plutonium will be removed from the SRS under the preferred option. This chapter provides the remaining information requested by Congress.

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2. U.S. Plutonium Disposition Program Evolution

In early 1994, DOE's National Laboratory and independent experts examined 37 different plutonium disposition technology options. Options ranged from conventional reactor irradiation approaches to concepts that considered shooting plutonium into space or burying it under the ocean floor. A screening report was issued in March 1995 which reduced the options from 37 to 11. These remaining options were divided into three groups: irradiation, including both existing and advanced reactors (five options), immobilization (four options), and direct geologic disposal (two options). These options were subsequently evaluated in a Programmatic Environmental Impact Statement. In January 1997, following technical, cost, and nonproliferation analyses as well as extensive public participation, a Final Programmatic Environmental Impact Statement, and a Record of Decision, the Department announced its intention to pursue a hybrid plutonium disposition strategy that utilizes immobilization and irradiation of plutonium in mixed oxide (MOX) fuel in existing, domestic reactors. The strategy entails the construction and operation of three major facilities for plutonium disposition.

- A pit disassembly and conversion facility (PDCF) to convert surplus U.S. plutonium weapons components (pits) into an unclassified oxide form suitable for disposition and inspection.

- A MOX fuel fabrication facility (MOX FFF) to fabricate surplus plutonium oxide into MOX fuel for irradiation in existing U.S. commercial nuclear reactors.

- A plutonium immobilization plant (PIP) to immobilize surplus non-pit plutonium in a ceramic material that is then surrounded by vitrified high-level radioactive waste.

Both disposition technologies (immobilization and irradiation) would effectively convert the surplus plutonium to forms that meet the Spent Fuel Standard, making it as inaccessible and unattractive for weapons as the much larger and growing inventory of plutonium that exists in spent nuclear fuel from commercial power reactors.[1]

The Spent Fuel Standard

The National Academy of Sciences (NAS) recommended the Spent Fuel Standard for disposing of surplus fissile material. Meeting the Spent Fuel Standard means making a material as inaccessible and unattractive for weapons use as the much larger and growing inventory of plutonium that exists in spent nuclear fuel from commercial nuclear power reactors. Plutonium meeting this standard is unattractive for several reasons, including its high radiation barrier, large weight and size, and physical and chemical composition. These characteristics make it difficult to transport, conceal, and process the plutonium for use in nuclear weapons.[1]

Still undecided at the time of the 1997 Record of Decision was the location(s) where plutonium disposition would take place and the amount of material to be dispositioned by each technology. Since this disposition effort was considered to be a major federal action under the National Environmental Policy Act (NEPA), detailed site-specific facility design and construction activities could not begin until completion of the appropriate additional NEPA reviews. It was not until March 1999 that the Department awarded a contract to a consortium of Duke Engineering & Services, COGEMA, and Stone & Webster (DCS) to initiate design efforts for the MOX FFF. In August 1999, the Department awarded a contract to Raytheon Engineers and Constructors (now Washington Group International) to initiate design efforts for a PDCF. In January 2000, following completion of a follow-on Environmental Impact Statement and a Record of Decision, DOE announced that the Savannah River Site had been selected as the location for all three plutonium disposition facilities, together with a decision that up to 33 MT of plutonium would be dispositioned via MOX/irradiation and up to 17 MT of plutonium via

[1] No viable alternative to the Spent Fuel Standard has been developed in subsequent NAS reviews of the standard.

immobilization. As of November 2001, design of the MOX FFF was about 60% complete, and design of the PDCF was about 25% complete.

As a result of reductions in the program's FY 2002 budget, several adjustments to the plutonium disposition program plans have been required. Construction of the MOX FFF has been delayed by one year from FY 2003 to FY 2004. Construction of the PDCF and the PIP would take place sequentially and follow later in time to reduce peak annual funding requirements. As a result in the delay in construction of the PIP, design of the PIP was suspended in early FY2002 following completion of conceptual design.

The Administration-directed review of the plutonium disposition program has resulted in a decision to make additional changes to the program. These changes are described in Chapter 5 of this report.

3. Methodology for Screening of Options

3.1 Overall Approach

To address the concerns of the Administration and to assist in selecting and defining options to restructure the U.S.-Russia cooperative plutonium disposition program, the following criteria were developed by the Department of Energy and the Department of State:

Criteria for Selecting and Defining Options

- Consistent with the Administration's overall strategic approach to Russia and our national energy and nonproliferation strategies, and supportive of the national security objective of reducing the risk that Russian weapons-usable nuclear materials will be diverted;
- Likely to attract support and commitment from the Russian government;
- Compatible with U.S. commitments to other countries and likely to receive necessary support from international partners;
- Based on a sound financial plan, with minimal risk of substantial unfunded future requirements for U.S. funding;
- Technologically feasible, and able to be completed within stable and predictable cost estimates and schedules.
- Supportive of DOE domestic programs for plutonium management and environmental remediation;
- Minimally at risk for delay or cancellation for environmental, regulatory, political, or other reasons.

For the U.S. program, DOE was also directed to evaluate utilization of advanced fuel cycle and reactor technologies currently under development.

The overall approach used for the Administration-directed review began with the selection and definition of options for U.S. plutonium disposition. Next, criteria were developed against which the options could be evaluated. The evaluation of the options relative to these criteria resulted in the selection of the preferred option.

3.2 Methodology for Selecting U.S. Options

3.2.1 Options Screening

To develop a list of options for modifying the existing U.S. plutonium disposition program, a broad array of technologies, facilities, locations, and operating parameters were considered. As a starting point, the 1995 report, *Summary Report of the Screening Process to Determine Reasonable Alternatives for Long-Term Storage and Disposition of Weapons-Usable Fissile Materials*, was revisited. This report evaluated and screened 37 candidate options for U.S. plutonium disposition (see text box). In October 2001, several members of the original screening committee and additional DOE and national laboratory staff met to review the 1995 effort and to consider the effects, if any, of new developments on the results of the 1995 screening. The purpose of this new review was to determine whether developments during the intervening years supported revised conclusions or presented new opportunities to optimize the U.S. plutonium disposition program. The 2001 review examined again each of the options reviewed in 1995 and four new options that have been suggested by various parties since that time.

The 2001 re-screening identified seven reasonable technology options for further evaluation. Five of these options also had been considered reasonable in the 1995 screening process. One option (Disposal to Waste Isolation Pilot Plant (WIPP)) had been eliminated in 1995 for disposal of large quantities of plutonium, but was now recognized as a reasonable disposition option for a limited amount of plutonium. The seventh and final reasonable option, Euratom MOX Fabrication/U.S. Reactor Burning was new and had not been considered in the 1995 screening.

Seven Reasonable Technology Options Identified in 2001 Re-Screening

1. Disposal to WIPP (Eliminated in 1995)
2. Ceramic Immobilization
3. Euratom MOX Fabrication / Euratom Reactor Burning
4. Existing Light Water Reactors
5. CANDU Heavy Water Reactors
6. No Disposition Action (Continued Storage)
7. Euratom MOX Fabrication / U.S. Reactor Burning (New Option)

3.2.2 Narrowing the Options & Scenarios

The resulting disposition options selected for the Administration-directed review were derived from the 2001 re-screening effort, input from the Administration, and input from proponents of other alternatives.

Twelve new, distinct disposition options were developed that combine several technical approaches.

- Six MOX disposition options, created by combining one or more technologies (existing Light Water Reactors (LWRs), ceramic immobilization, disposal as waste) and specifying different combinations of facilities, material inventories, and disposition rates;
- Two advanced reactor disposition options; and
- Four non-irradiation disposition options.

Two reasonable technology options from the 2001 re-screening, Euratom Reactor Burning and CANDU Heavy Water Reactors, were considered but not used to develop any disposition options because commercial reactor services are already under contract in the United States.

3.2.3 Coupling vs. De-Coupling

The disposition options considered in this evaluation are divided into two categories based on whether the options are consistent with the intent of the September 2000 U.S.-Russian Plutonium Management and Disposition Agreement, and on whether it is judged that Russia could be persuaded to agree with the option. A U.S. decision to depart from or substantively change the Agreement could have a distinct negative impact on the likelihood that Russia will continue with its own plutonium disposition program.

For the U.S. options, the key factor considered in determining whether an option would be acceptable to Russia is whether the isotopic composition of the plutonium is degraded so that it is no longer considered weapons grade. For the U.S. program, only options including one or more reactor irradiation technologies to disposition a substantial portion of the plutonium inventory were recognized as being consistent with the PMDA and acceptable to Russia, and were categorized as "coupled." U.S. options that depend primarily on other approaches, in particular storage and immobilization, were recognized as unacceptable to Russia and inconsistent with the PMDA. While immobilized forms can meet the Spent Fuel Standard, an internationally recognized standard for protecting fissile material from proliferation threats, Russia does not view immobilization as an acceptable approach unless the isotopic composition of the plutonium is also degraded. The supply of separated reactor-grade plutonium in the United States is not sufficient to provide for degradation of isotopic composition by mixing reactor-grade and weapons-grade plutonium prior to immobilization or storage. Thus, the immobilization- and storage-based U.S. options were categorized as "de-coupled." Tables 3-1 and 3-2 present the nine coupled and four de-coupled U.S. options considered in the evaluation.

Table 3-1. U.S. Coupled Options for Plutonium Disposition

Option Type	Number	Name
MOX	0	March 2001 Cost Report
	1a	Project Baseline – One-Year Delay [in the Start of Construction of the MOX FFF] from Cost Report
	1b	Project Baseline with Accelerated MOX Throughput
	2	MOX with 34 MT Pu – All PIP Material Purified at F-Canyon
	3a	MOX Only with High-Quality Pu – Some PIP Material Purified at Enhanced MOX FFF
	3b	MOX Only with High Quality Pu – Some PIP Material Purified at F-Canyon
	4	Eurofab / U.S. Burn
Advanced Reactors	5a	Advanced Reactors – GT-MHR
	5b	Advanced Reactors – Thorium Fuel Cycle

Table 3-2. U.S. De-Coupled Options for Plutonium Disposition

Option Type	Number	Name
Immobilization	1a	Immobilize at SRS (13 MT)
	1b	Immobilize at SRS (34 MT)
Storage	2	Store in Place
	3	Consolidate / Store at Fewer Sites

Coupled Option 0, which corresponded to the U.S. Plutonium Disposition Program outlined in DOE's March 2001 Cost Report to Congress, is identified in this analysis but is not evaluated because budget reductions have already rendered the approach moot. In its report accompanying the Energy and Water Development Appropriations for FY 2001 (Public Law 106-377), Congress directed DOE to provide a detailed report providing the full costs of the Fissile Materials Disposition Program. The Cost Report was to include a cost and schedule baseline, information on funding to be contributed by Russia and other countries in support of the initiative, and describe how U.S.-Russian parity would be maintained. The report was completed in March 2001, and has been held since then by the Office of Management and Budget pending the review by the Administration. The plutonium disposition approach described in the Cost Report is the dual-track (MOX plus immobilization) disposition scenario presented in this evaluation as Option 0, and corresponds to a total cost for the U.S. program of $6.2 billion. In addition to dispositioning the 34 MT baseline inventory, this option also dispositions another 4.6 MT of additional non-weapons-grade plutonium (through immobilization) dispositions an additional 7.4 MT of weapons-grade material from potential future surplus declarations through MOX irradiation. Options 1a and 1b in this report use the same dual-track approach, but include changes that reduce overall cost.

All options based primarily on reactor irradiation are considered "coupled," and could be implemented under a reciprocal U.S.-Russia plutonium disposition agreement. Each of the coupled options requires a similar combination of facilities for pit disassembly/plutonium conversion/purification, fuel fabrication, and irradiation. Some options include existing facilities, while others use to-be-constructed facilities. In addition, some options require facilities for immobilization and disposal. Table 3-3 lists the facilities that would be required under each U.S. coupled option.

Table 3-3. Facilities Necessary for U.S. Coupled Options [a,b]

Option Name	Pit Disassembly and Pu Conversion		Fuel Fabrication		Other Facilities		
	PDCF	Canyons	MOX	Other FFF	Immob.	Waste [f]	Reactors [g]
0. March 2001 Cost Report	❍		❍		❍, ● [e]		●(4)
1a. Project Baseline – One-Year Delay [in the Start of Construction of the MOX FFF] from Cost Report	❍		❍		❍, ● [e]		●(4)
1b. Project Baseline with Accelerated MOX Throughput	❍		❍		❍, ● [e]		●(6)
2. MOX with 34 MT Pu – All PIP Mat'l Purified at F-Canyon	❍	●	❍				●(6)
3a. MOX Only with High-Quality Pu – Some PIP Mat'l Purified at Enhanced MOX FFF	❍		❍ [d]			●	●(6)
3b. MOX Only with High-Quality Pu – Some PIP Mat'l Purified at F-Canyon	❍	●	❍			●	●(6)
4. Eurofab / U.S. Burn	❍ [c]		●				●(6)
5a. Advanced Reactors – GT-MHR	❍			❍			❍(12)
5b. Advanced Reactors – Thorium Fuel Cycle	❍ [c]			❍			● [h] (TBD)

[a] ❍ = New facility to be constructed.
● = Existing facility.
[b] All facilities require use of a geologic repository (not listed above) for disposal of final forms.
[c] Under these options, the PDCF would be enhanced with an aqueous processing system for gallium and impurities removal.
[d] Under this option, the MOX FFF would be enhanced with a more robust aqueous processing system for impurities removal.
[e] First-stage immobilization requires the construction of a Plutonium Immobilization Plant (PIP). Second stage immobilization would be performed at the existing Defense Waste Processing Facility at SRS.
[f] Costs for disposal as waste are not included.
[g] Number of needed existing reactors is shown in parentheses.
[h] Existing reactors used for irradiation in thorium fuel cycle would require modification, and the number of such reactors has not been determined.

Each of the "de-coupled" U.S. options focuses on storage and immobilization approaches that are not consistent with the intent of the PMDA and would likely not be considered acceptable to Russia. Since DOE would incur storage costs until all of the surplus plutonium has been disposed of (regardless of the disposition option), only incremental storage costs have been identified. Assumptions pertaining to storage costs appear in the following de-coupled options: Immobilize at SRS (13 MT or 34 MT), Store in Place, and Consolidate/Store at Fewer Sites.

3.3 Evaluation Criteria

DOE systematically assessed each of the U.S. options against a set of critical attributes or evaluation criteria. While the criteria listed below are not ranked in order of importance, certain criteria figure more prominently in some options than others depending on the individual or unique characteristics of each option or what is known about the approach today.

1. **Costs and Schedule.** Costs to implement and estimated annual costs over time. Projected schedule, including key milestones (dates for agreements involving non-U.S. government parties, beginning and end of facility capital construction and operations activities corresponding to the projected cost profile). Plutonium disposition rate, in MT/year. Robustness of cost and schedule data. Major factors (e.g., licensing issues, technology maturity, nonproliferation assurances, political factors) that contribute to the confidence and uncertainty levels associated with the projected cost and schedule.

2. **Technology Maturity.** The current state of development, research, and industrial experience, including licensing experience, associated with the technologies. Technological risks and uncertainties, including safety and environmental issues.

3. **Nonproliferation and Nuclear Material Security.** The nature of the proliferation risks and present uncertainties. Nonproliferation and irreversibility assurances. The relationship between nonproliferation issues and negotiability between the United States and Russia. Issues affecting other nonproliferation programs and activities.

4. **Sensitivities.** For the U.S. options, this factor addresses the following four areas:

    a) *Budget Impacts.* Annual budget appropriations that would be required to support the option.
    b) *Impact on States and Other DOE Programs.* The effect the option would have on DOE activities in various states. Political sensitivities and potential barriers (e.g., existing agreements between DOE and states) that would affect or be affected by implementation of this option. The effect the option would have on other DOE activities and plans in other programs (e.g., DOE Office of Environmental Management), and the effect the other activities and plans could have on the option.
    c) *Public and NGO Response.* How it is expected that the public and NGOs would respond to the option.
    d) *International Factors.* Involvement of any non-U.S. governments and other institutions (e.g., EU countries, Russia), including uncertainties concerning their support or resistance, and the impact of their position on implementation of the option.

5. **Other Factors.** Any factors having a significant bearing on the evaluation which are not addressed in the other criteria.

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4. Evaluation of U.S. Options

4.1 Approach to Evaluating Options

This section examines twelve options for the disposition of surplus U.S. weapons-grade plutonium. All options assume the disposition or storage of 34 metric tons (MT) of plutonium. Some of the options are consistent with the intent of the September 2000 U.S.-Russian Plutonium Management and Disposition Agreement (coupled options), and others are not (de-coupled options).

The twelve options selected for examination were derived from an updated review of the 1995 effort in which 37 candidate options for U.S. plutonium disposition were evaluated and screened. DOE also considered additional options based on input from the Administration and from proponents of other alternatives.

The options fall into five general groups:

- Dual track options employing existing commercial nuclear reactors for disposition of part of the 34 MT and immobilization for disposition of plutonium not dispositioned in reactors.

- Mixed oxide (MOX) only options employing commercial nuclear reactors for disposition of the entire 34 MT.

- Advanced reactor options entailing development of new reactor technologies for disposition of the entire 34 MT.

- Immobilization options for disposition of all or part of the 34 MT. No reactor-based disposition would be used, and plutonium that is not immobilized would be stored.

- Storage options for the entire 34 MT.

In this chapter, each option is examined relative to: (1) costs and schedule, (2) technology maturity, (3) nonproliferation and material security factors, (4) sensitivities (including budget requirements, impacts on states and other DOE programs, public and NGO response, and international factors), and (5) other factors as appropriate.

Tables 4-1 and 3-3 summarize the options considered in terms of, respectively, their scope and facilities utilized.

Table 4-1. U.S. Plutonium Disposition Options Evaluated

Option Type	Summary Description
Coupled Options	
MOX 1a	• Current project baseline • MOX fuel with throughput of 2 MT/year (25.6 MT) • Immobilization at 1.3 MT/year (8.4 MT)
MOX 1b	• Expedited baseline • MOX fuel throughput increases to 3.5 MT/year (25.6 MT) • Immobilization at 1.3 MT/year (8.4 MT)
MOX 2	• MOX only (34 MT at 3.5 MT/year) • No immobilization • Use of old and new F-Canyon facilities to support MOX feed
MOX 3a	• MOX only (34 MT at 3.5 MT/year) • No immobilization • Enhanced aqueous purification process to support MOX feed • Clean plutonium substituted for 2 MT of material disposed as waste
MOX 3b	• MOX only (34 MT at 3.5 MT/year) • No immobilization • Existing old F-Canyon facilities used to support MOX feed • Clean plutonium substituted for 2 MT of material disposed as waste
MOX 4	• MOX fuel fabricated in Europe and irradiated in United States (34 MT at 3.5 MT/year)
Advanced Reactor 5a	• 34 MT to gas-cooled modular helium reactors at 3.5 MT/year
Advanced Reactor 5b	• 34 MT to reactors using thorium/plutonium or thorium/uranium/plutonium fuels at 3.5 MT/year
De-Coupled Options	
Immobilization 1a	• 13 MT to immobilization at 1.3 MT/year • Continued storage of remaining material
Immobilization 1b	• 34 MT to immobilization at 5 MT/year
Storage 2	• Continued storage at existing sites
Storage 3	• Storage at reduced number of sites following consolidation

4.2 MOX Options

For each MOX option, the following discussions summarize the relative advantages and disadvantages with respect to the evaluation criteria listed in Section 3.3.

#1a: Project Baseline – One-Year Delay [in the Start of Construction of the MOX FFF] from Cost Report

Description: This option was the current project baseline at the time of the Administration-directed review. It uses the same disposition strategy, facilities, technologies, and baseline plutonium inventory as the Cost Report option. This includes the disposition of 25.6 MT of surplus plutonium through irradiation and 8.4 MT through immobilization at rates of 2 MT/year and 1.3 MT/year, respectively. Three new facilities would be constructed at the Savannah River Site (SRS): the Pit Disassembly and Conversion Facility (PDCF), MOX Fuel Fabrication Facility (MOX FFF), and the Plutonium Immobilization Plant (PIP). Costs and schedule have been adjusted from the March 2001 Cost Report to accommodate reductions in the program's FY 2002 and FY 2003 budgets. Start of construction of the MOX FFF is delayed by one year from FY 2003 to FY 2004. Construction of the PDCF and the PIP follow sequentially later in time.

$5.4 B Total Cost to Implement * (* in FY 2001 constant dollars)	FY02	FY03	FY04	FY05	FY06
	$173 M	$207 M	$436 M	$472M	$511 M
	5-Year Budget Profile *				

Costs and Schedule. The total projected cost to implement this option is approximately $5.4 billion (constant FY 2001 dollars). Initial fabrication of plutonium into MOX fuel occurs in FY 2008, and initial immobilization of plutonium occurs in FY 2014. The project is completed in FY 2020. Confidence in PDCF and PIP costs is moderate. Confidence in MOX costs is high.

Technology Maturity. The PDCF technology has been demonstrated on weapons pits since 1998. Technology demonstrations are continuing to ensure that capability to process all pit types will be established. This work is expected to be complete in FY 2003, after which the demonstration equipment will be used to refine operating procedures and to process selected materials. The PDCF would be the first application of the technology on an industrial scale. Preliminary design of the PDCF is underway, and final design is scheduled for completion in FY 2004.

The MOX technology is well established and mature. The aqueous purification, fuel fabrication, and reactor irradiation technologies are based on proven processes used in Europe since the 1960s. Modifications for use in this program would be relatively minor. Final design of the MOX FFF is underway and is scheduled for completion in December 2002.

The PIP technology is currently under development. Demonstrations with plutonium materials and high level waste have not yet been conducted and are not expected to be complete until FY 2008. The design of the PIP is currently suspended, and final design is scheduled for completion in FY 2011.

Nonproliferation and Nuclear Material Security. Both the spent MOX fuel and the immobilization waste form would meet the Spent Fuel Standard. Safeguards and security provisions of the DOE and Nuclear Regulatory Commission (NRC) (in the case of the MOX facilities) would be applied to material handling and transportation. The option would be amenable to bilateral and international monitoring after the material leaves the PDCF.

Sensitivities

Budget Impacts. Building the three facilities in sequence lowers peak year funding requirements relative to the March 2001 Cost Report and accommodates current and projected FY 2002 and FY 2003 budgets. Facility operations extend one year later than projected in the March 2001 Cost Report.

Impact on States and Other DOE Programs. This option would maintain DOE's commitment to the State of South Carolina to provide a pathway out of the State for plutonium brought to SRS for disposition. This, in turn, would facilitate DOE Office of Environmental Management (DOE-EM) efforts to close the Rocky Flats Plant by 2006 and would save hundreds of millions of dollars annually in associated storage costs. This option would also enable plutonium to be moved from other DOE sites for disposition.

Public and NGO Response. This option would preserve the elements of DOE's 1997 and 2000 Records of Decision for plutonium disposition. Strong and divided public opinion regarding the merits of MOX vs. immobilization would continue to exist. Delay in completion of PIP would be interpreted by MOX opponents as an attempt to eliminate immobilization and might further increase their opposition to MOX.

International Factors. This option would be consistent with the existing U.S.-Russian PMDA and with past U.S. policy statements. Renegotiation of some of the PMDA milestones would be required.

Assessment

#1a: Project Baseline – One-Year Delay [in the Start of Construction of MOX FFF] from Cost Report

This option meets program objectives within the constraints imposed by the FY 2002 and FY 2003 budgets. Alternative options have been evaluated to improve program performance relative to this option and are described in this report.

#1b: Project Baseline with Accelerated MOX Throughput

Description: This option differs from the current project baseline, Option 1a, only in that plutonium is processed through the PDCF and the MOX FFF at their full operating capacity of 3.5 MT/yr. This option would require the addition of two existing commercial nuclear reactors to the four currently under contract.

$ 4.6 B Total Cost to Implement *	FY02	FY03	FY04	FY05	FY06
	$173 M	$207 M	$436 M	$472 M	$511 M
* in FY 2001 constant dollars	**5-Year Budget Profile ***				

Costs and Schedule. The total projected cost to implement this option is approximately $4.6 billion (constant FY 2001 dollars). Initial fabrication of plutonium into MOX fuel occurs in FY 2008, and initial immobilization of plutonium occurs in FY 2014. The project is completed in FY 2020. Confidence in PDCF, MOX, and PIP costs is as described for Option 1a.

Technology Maturity. The maturity of PDCF, MOX, and PIP technology is as described for Option 1a.

Nonproliferation and Nuclear Material Security. These factors are the same as those described for Option 1a.

Sensitivities

Budget Impacts. Building the three facilities in sequence lowers peak year funding requirements relative to the March 2001 Cost Report and accommodates current and projected FY 2002 and FY 2003 budgets. Completion of the MOX component of the program is accelerated by four years relative to Option 1a as a result of the increased MOX throughput, and overall project implementation costs are reduced by $800 million.

Impact on States and Other DOE Programs. These factors are the same as those described for Option 1a.

Public and NGO Response. These factors are the same as those described for Option 1a.

International Factors. This option would be consistent with the existing U.S.-Russian PMDA and with past U.S. policy statements. A renegotiation of some of the PMDA milestones would be required, but the accelerated date for completion of the MOX component of the program would generally be viewed favorably.

Other Factors. Acceleration of the completion date for the MOX component of the program would raise questions from members of Congress and others who consider it important that U.S. and Russian plutonium disposition programs proceed in parallel. It is not clear whether the Russian plutonium disposition program could be accelerated to keep pace with the U.S. program if this option is chosen.

Assessment
#1b: Project Baseline with Accelerated MOX Throughput

This option meets program objectives within the constraints imposed by the FY 2002 and FY 2003 budgets. By increasing the rate of plutonium disposition compared to Option 1a (Project Baseline), the overall project costs are reduced by $800 million. Accordingly, this option is more attractive from a cost standpoint than the current project baseline, Option 1a. Successful implementation requires obtaining two additional commercial reactors to participate in the U.S. program and expanding the rate of plutonium disposition in Russia.

#2: MOX with 34 MT Pu – All PIP Material Purified at F-Canyon

Description: This option eliminates the immobilization (PIP) element of the current baseline option. The non-pit plutonium that would have been immobilized would be processed in existing operating and 15 year old (but never operated) F-Canyon facilities at SRS to produce plutonium oxide suitable for use in the MOX FFF. Under this option, all 34 MT of surplus weapons-grade plutonium would be converted to MOX fuel and irradiated in existing U.S. commercial nuclear reactors at 3.5 MT/year. This option requires the addition of two existing commercial nuclear reactors to the four currently under contract.

$ 5.0 B Total Cost to Implement *	FY02	FY03	FY04	FY05	FY06
	$240 M	$321 M	$561 M	$638 M	$683 M
* in FY 2001 constant dollars	5-Year Budget Profile *				

Costs and Schedule. The total projected cost to implement this option is approximately $5.0 billion (constant FY 2001 dollars). These costs are more than those of Option 1b primarily because the canyon operations in this option, particularly those involving processes that have never been operated, are more expensive than the PIP costs in Option 1b. Initial fabrication of plutonium into MOX fuel occurs in FY 2008. The project is completed in FY 2019. Confidence in PDCF and MOX costs is as described for Option 1a. Confidence in costs to use F-Canyon facilities is low to moderate.

Technology Maturity. The maturity of PDCF and MOX technology is as described for Option 1a. Plutonium materials have been processed in the F-Canyon facilities for over 40 years. However, experience with the specific materials and quantities for this option is limited. Other F-Canyon facilities that have never been operated would have to be modified and qualified for the processes needed for this option. There is a significant additional risk introduced by depending on this 40-year-old facility.

Nonproliferation and Nuclear Material Security. These factors are essentially the same as those described for Option 1a.

Sensitivities

Budget Impacts. The benefits of building the MOX FFF and the PDCF in sequence and increasing facilities throughput are the same as described for Option 1b. However, overall project implementation costs would be $400 million more than that for Option 1b. Use of the F-Canyon facilities would result in higher costs relative to the use of the PIP.

Impact on States and Other DOE Programs. The factors related to commitments to South Carolina and site closure are the same as described for Option 1a. Elimination of the PIP would result in some loss of job opportunities associated with facility construction and operation. This would be offset to some extent by additional work in the F-Canyon facilities. Use of F-Canyon facilities beyond their planned life would require coordination with other DOE program elements regarding responsibility for surveillance, maintenance, and other matters. Use of F-Canyon facilities that have never been operated would require negotiation with other DOE program elements regarding cleanup responsibilities.

Public and NGO Response. This option changes key elements of DOE’s 1997 and 2000 Records of Decision for plutonium disposition. Additional National Environmental Policy Act (NEPA) review and associated opportunities for public involvement would be required. Strong and divided public opinion regarding the merits of MOX vs. immobilization would continue to exist. Elimination of immobilization would likely further increase opposition to MOX by certain NGOs, many of whom also strongly oppose expansion of activities and extension of service life of F-Canyon.

International Factors. This option would alter the existing U.S.-Russian PMDA and would be inconsistent with past U.S. policy statements on immobilizing part of its plutonium. However, support would be expected from Russia because it more closely aligns the U.S. program with that of Russia. Renegotiation of some of the PMDA terms and milestones would be required.

Other Factors. These factors are the same as those described for Option 1b.

Assessment
#2: MOX with 34 MT Pu – All PIP Material Purified at F-Canyon

This option meets program objectives within the constraints imposed by the FY 2002 and FY 2003 budgets. By increasing the rate of plutonium disposition compared to Option 1a, overall project costs are reduced. However, no cost saving is achieved from operating F-Canyon facilities instead of constructing the PIP, so this option is more expensive than Option 1b.

Overall, this option is no more attractive than the accelerated project baseline, Option 1b. It will require additional NEPA review on the part of DOE with associated public participation. Issues are raised concerning public opposition to continued operation of F-Canyon facilities. Issues are also raised with other DOE program elements regarding responsibilities for F-Canyon activities and costs.

#3a: MOX Only with High-Quality Pu – Some PIP Material Purified at Enhanced MOX FFF

Description: This option eliminates the immobilization (PIP) element of the current baseline option. 6.4 MT of the non-pit plutonium that would have been immobilized would be purified using enhanced aqueous polishing in the MOX FFF, and 32 MT of the baseline inventory would be converted to MOX fuel and irradiated in existing commercial nuclear reactors at 3.5 MT/year. This option would require the addition of two existing commercial nuclear reactors to the four currently under contract. The remaining 2 MT of the baseline inventory that could not be economically converted into MOX fuel would be disposed as waste and would be replaced with 2 MT of surplus plutonium from future declarations, resulting in disposition of 34 MT.

$ 3.8 B	**FY02**	**FY03**	**FY04**	**FY05**	**FY06**
Total Cost to Implement *	$152 M	$221 M	$451 M	$485 M	$565 M
* in FY 2001 constant dollars	**5-Year Budget Profile ***				

Costs and Schedule. The total projected cost to implement this option is approximately $3.8 billion (constant FY 2001 dollars). These costs are substantially lower than those of Option 1b and Option 2 because enhancing the capability of the aqueous processing equipment in the MOX FFF is much less expensive than design, construction, and operation of the PIP or use of the F-Canyon facilities. Initial fabrication of plutonium into MOX fuel occurs in FY 2008. The project is completed in FY 2019. Confidence in PDCF costs is moderate. Confidence in MOX costs is high.

Technology Maturity. The maturity of PDCF and MOX technology is as described for Option 1a. Modifications to the MOX FFF to enhance the aqueous processing capability employ mature technology. Although completion of the MOX FFF final design would be delayed by approximately nine months, design would still be completed in FY 2003, and the overall disposition schedule would not be affected.

Nonproliferation and Nuclear Material Security. These factors are essentially the same as those described for Option 1a.

Sensitivities

Budget Impacts. The benefits of building the MOX FFF and the PDCF in sequence and increasing facilities throughput are the same as described for Option 1b. Furthermore, enhancing the aqueous processing capability of the MOX FFF would result in significant savings relative to the use of the PIP or the F-Canyon facilities. Therefore, overall project implementation costs would be reduced relative to Option 1a.

Impact on States and Other DOE Programs. The factors related to commitments to South Carolina and site closure are the same as described for Option 1a. Elimination of the PIP would result in some loss of job opportunities associated with facility construction and operation.

Public and NGO Response. These factors are the same as those described for Option 2. Elimination of immobilization would likely further increase opposition to MOX by certain NGOs. These organizations would also oppose expansion of aqueous purification activities due to increased waste generation, but the contentions regarding this issue are already under review as part of the MOX FFF licensing proceeding. Since the aqueous processing is in a lightly shielded facility that could not be used for spent fuel processing, there would not be a concern that DOE was creating additional spent fuel processing capability.

International Factors. These factors are the same as those described for Option 2.

Other Factors. These factors are the same as those described for Option 1b.

Assessment

#3a: MOX Only with High-Quality Pu – Some PIP Material Purified at Enhanced MOX FFF

This option meets program objectives within the constraints imposed by the FY 2002 and FY 2003 budgets. By increasing the rate of plutonium disposition compared to Option 1a, the overall project costs are reduced. Substantial cost saving is achieved relative to Option 1b by enhancing the aqueous processing capability of the MOX FFF instead of constructing the PIP. Overall project costs are reduced by $1.6 billion relative to Option 1a.

Overall, this option is considerably more attractive than the accelerated project baseline, Option 1b. Total project costs are substantially lower, without compromising ability to achieve program objectives, due to the elimination of one major new facility. It will require additional NEPA review on the part of DOE with associated public participation. Successful implementation requires obtaining two additional commercial reactors to participate in the program and expanding the rate of plutonium disposition in Russia.

#3b: MOX Only with High-Quality Pu – Some PIP Material Purified at F-Canyon

Description: This option also eliminates the immobilization (PIP) element of the current baseline option. 6.4 MT of non-pit plutonium that would have been immobilized would be processed in existing, operating F-canyon facilities at SRS to produce plutonium oxide suitable for use in the MOX FFF. In contrast to Option 2, 15-year-old SRS facilities at F-Canyon that have never been operated would not be used. 32 MT of the baseline inventory would be converted to MOX fuel and irradiated in existing commercial nuclear reactors at 3.5 MT/year. This option would require the addition of two existing commercial nuclear reactors to the four currently under contract. The remaining 2 MT of the baseline inventory that could not be economically converted into MOX fuel would be disposed as waste and would be replaced with 2 MT of surplus plutonium from future declarations, resulting in disposition of 34 MT.

$ 4.0 B	FY02	FY03	FY04	FY05	FY06
Total Cost to Implement *	$208 M	$258 M	$500 M	$536 M	$532 M
* in FY 2001 constant dollars	5-Year Budget Profile *				

Costs and Schedule: The total projected cost to implement this option is approximately $4.0 billion (constant FY 2001 dollars). These costs are lower than those of Option 1b because use of the existing F-Canyon facilities costs less than design, construction, and operation of the PIP. Initial fabrication of plutonium into MOX fuel occurs in FY 2008. The project is completed in FY 2019. Confidence in PDCF costs is moderate. Confidence in MOX costs is high. Confidence in costs to use existing, operating F-Canyon facilities is low to moderate.

Technology Maturity. The maturity of PDCF and MOX technology is as described for Option 1a. The maturity of F-Canyon technology is as described for Option 2.

Nonproliferation and Nuclear Material Security. These factors are essentially the same as those described for Option 1a.

Sensitivities

Budget Impacts. The benefits of building the MOX FFF and the PDCF in sequence and increasing facilities throughput are the same as described for Option 1b. Use of existing, operating F-Canyon facilities would result in some savings relative to design, construction, and operation of the PIP. Overall project implementation costs would be reduced by $1.4 billion relative to Option 1a.

Impact on States and Other DOE Programs. These factors are essentially the same as those described for Option 2.

Public and NGO Response. These factors are essentially the same as those described for Option 2.

International Factors. These factors are essentially the same as those described for Option 2.

Other Factors. These factors are essentially the same as those described for Option 1b.

Assessment

#3b: MOX Only with High-Quality Pu – Some PIP Material Purified at F-Canyon

This option meets program objectives within the constraints imposed by the FY 2002 and FY 2003 budgets. By increasing the rate of plutonium disposition compared to Option 1a, the overall project costs are reduced. Some cost saving is achieved from operating existing F-Canyon facilities instead of constructing the PIP, but total savings are less than those of Option 3a.

Overall, this option is more attractive than the accelerated project baseline, Option 1b. Overall project costs are improved somewhat, but costs of adapting and operating a 40-year old facility for a new mission are uncertain. It will require additional NEPA review on the part of DOE with associated public participation. Issues are raised concerning public opposition to continued operation of F-Canyon facilities. Issues are also raised with other DOE program elements regarding responsibilities for F-Canyon activities and costs. Option 3a is judged to be significantly more attractive overall because it requires fewer interfaces to implement and its cost is lower and less uncertain.

#4: Eurofab / U.S. Burn

Description: This option would convert 34 MT of surplus U.S. weapons-grade plutonium to oxide, ship that oxide to an existing, commercial European fuel fabrication facility, use it to fabricate light water reactor MOX fuel, and ship the finished fuel back to the United States for irradiation in existing, domestic commercial reactors. European fabrication facilities having excess production capacity could potentially be used for this purpose. Some of these facilities would need to be re-licensed for possession of weapons-grade plutonium. The removal of gallium and other impurities from the plutonium could possibly be done in Europe as well if facilities were re-licensed, but would more likely be done in the United States, in the PDCF or a stand-alone facility, prior to shipment.

$ 3.3 B Total Cost to Implement * (* in FY 2001 constant dollars)	**FY02**	**FY03**	**FY04**	**FY05**	**FY06**
	$118 M	$173 M	$195 M	$326 M	$311 M
	5-Year Budget Profile *				

Costs and Schedule. The total projected cost to implement this option is approximately $3.3 billion (constant FY 2001 dollars). Initial fabrication of plutonium into MOX fuel would occur in FY 2010. The project would be completed in FY 2022. Confidence in PDCF costs is moderate. Confidence in MOX costs is low, in contrast to other MOX options, due to lack of detailed discussions with European fuel fabricators and uncertainty regarding plutonium purification options and transportation requirements. Transportation costs are particularly uncertain. These factors also result in lower confidence in project schedule compared to the other MOX alternatives.

Technology Maturity. In contrast to all other MOX options, this option would use a fully mature MOX fabrication technology at a currently operating commercial fabrication facility. The maturity of PDCF technology is as described for Option 1a.

Nonproliferation and Nuclear Material Security. The international plutonium and MOX shipments would occur using secure transportation arrangements. Additional analyses accounting for new terrorist threats would need to be performed. Costs of new security requirements that may be imposed are uncertain at this time.

Sensitivities

Budget Impacts. Although aqueous purification capability would have to be provided in the PDCF or in a separate facility, eliminating the need for the MOX FFF at SRS would be expected to substantially reduce overall project implementation costs relative to other MOX options. This option accommodates current and projected FY 2002 and FY 2003 budgets.

Impact on States and Other DOE Programs. The factors related to commitments to South Carolina and site closure are the same as described for Option 1a. Elimination of the PIP and the MOX FFF would result in loss of job opportunities associated with facility construction and operation. This would probably lead to reduced program support in South Carolina.

Public and NGO Response. These factors are the same as those described for Option 2. Additional NEPA review and associated opportunities for public involvement would be required. Elimination of immobilization would likely further increase opposition to MOX by certain NGOs. These organizations would also strongly oppose large scale international shipping of plutonium feed material and finished MOX fuel assemblies and would likely intervene in the required NRC export licensing proceedings.

International Factors. These factors are essentially the same as those described for Option 2. In addition, extensive government-to-government negotiations would be required to establish terms and conditions under which this option could be implemented. At present, there have been no such discussions, even on a preliminary basis. Requirements for international shipment of materials are uncertain.

Other Factors. This option would require that a new major procurement effort be conducted to choose which of the three European fuel fabrication companies would participate in the program. Expressions of interest have not been solicited at this time. Not all of the candidate facilities are licensed to operate using weapons-grade plutonium. Concurrence of the commercial nuclear reactor owners, in whose reactors the MOX fuel would be irradiated, would have to be obtained.

Assessment
#4: Eurofab / U.S. Burn

Due to the complications associated with establishing a complex international venture, this option has a very uncertain schedule and very uncertain prospects for success. Although preliminary evaluations of cost indicate potential savings over the other MOX options, this option is less attractive than other MOX options.

4.3 Advanced Reactor Options

The following discussions include a summary evaluation of each of the two coupled advanced reactor options (Coupled options #5a and #5b).

#5a: Advanced Reactors – GT-MHR

Description: This option eliminates the immobilization (PIP) element of the current baseline option. Fuel fabricated from all 34 MT of surplus plutonium would be burned using the gas turbine modular helium reactor (GT-MHR). The GT-MHR is an advanced, high temperature gas-cooled reactor concept developed by General Atomics, a U.S. gas-cooled reactor vendor. A preliminary GT-MHR plant design is being developed in Russia with joint funding provided by the U.S., Russia, and other foreign interests to provide a supplemental disposition pathway for Russian surplus plutonium. Gas-cooled reactor proponents suggest that a joint U.S./Russian GT-MHR program, with reactors in both countries, could be used to disposition all 68 MT of U.S. and Russian surplus plutonium. Extensive technology development and testing is required. New facilities that would be constructed include the PDCF, a graphite fuel fabrication facility, and 12 GT-MHR modules grouped in three four-module plants to disposition 34 MT of plutonium at 3.5 MT/year.

$ 6.1 B Total Cost to Implement * * in FY 2001 constant dollars	FY02	FY03	FY04	FY05	FY06
	$178 M	$370 M	$314 M	$342 M	$451 M
	5-Year Budget Profile *				

Costs and Schedule. The total projected cost to implement this option is approximately $6.1 billion (constant FY 2001 dollars). Initial fabrication of plutonium into graphite fuel occurs in FY 2012, and the project is completed in FY 2032. Confidence in PDCF costs is moderate, as described in Option 1a. Confidence in fuel fabrication facility and reactor costs is low.

Technology Maturity. The maturity of PDCF technology is as described for Option 1a.

Although gas reactors have been built and operated in several countries around the world, including the United States, these plants were substantially different from the GT-MHR concept. The GT-MHR is made up of multiple reactor modules (as compared to the older single unit plants) and it incorporates many technological advancements. No operating experience exists with the advanced, modular GT-MHR plant configuration and, therefore, a significant amount of research, development and testing would be required to resolve technical and licensing issues before a plant could be constructed and operated.

Nonproliferation and Nuclear Material Security. The GT-MHR has the potential to achieve high plutonium-239 burnups and to produce spent fuel with very little residual plutonium-239. This low plutonium-239 content, coupled with the fact that gas reactor fuel processing is very difficult to perform, would make extraction of plutonium from the GT-MHR spent fuel unattractive to a potential proliferator. The potential nonproliferation advantages of the GT-MHR, however, do not necessarily make it more attractive than MOX to the United States and Russia for plutonium disposition. The high degree of technology development, coupled with the high cost and extended schedule requirements, may offset any potential nonproliferation advantage.

Sensitivities

Budget Impacts. The cost of developing, testing, and constructing the GT-MHRs and graphite fuel fabrication facilities would exceed the cost of any of the MOX disposition options being considered. Total funding requirements are projected to be $15.2 billion, far more than any other option considered, to cover the development of both a new fuel fabrication facility and 12 new reactor modules. However, the total projected project cost is reduced from this figure due to electricity sales revenues of $5 billion and an estimated residual value of the GT-MHR facilities of $4 billion. Completion of the program would be extended by 13 years. There have been assertions that, were the United States to build one module and it were to prove successful, commercial entities would build additional modules at their own cost. This would reduce the cost of this option to the government. However, the validity of this view cannot be established at this time, and thus it cannot be considered a valid basis for a current decision.

Impact on States and Other DOE Programs. This option would require consideration of many potential sites for development, testing, and construction of fuel fabrication and reactor facilities. Because SRS, the designated site for the PDCF, MOX FFF, and PIP in the current program, might not be selected for all or some of the new activities and facilities, this option might result in a decrease in expected SRS-related employment. Further, the uncertainty associated with development of GT-MHRs may bring into question the possibility of an early closure of the Rocky Flats Plant.

Public and NGO Response. This option does not preserve the elements of DOE's 1997 and 2000 Records of Decision for plutonium disposition. Additional NEPA review and associated opportunities for public involvement would be required. Elimination of immobilization would likely further increase opposition to irradiation by certain NGOs that already oppose MOX.

International Factors. International support for the GT-MHR option could be difficult to maintain due to the longer schedule and implied lack of urgency. This option would more significantly alter the existing U.S.-Russian PMDA, and renegotiation of some of the PMDA terms and milestones would be required. The Russian reaction to a shift towards GT-MHRs is uncertain.

Other Factors. Congressional support for the more expensive and lengthy GT-MHR would be more difficult to maintain, and the risks of not completing the plutonium disposition mission would be significantly higher.

Assessment
#5a: Advanced Reactors – GT-MHR

This option is more costly and dispositions plutonium more slowly than any of the MOX or MOX/immobilization options. The risks of failure or significant delay using this option are high because it depends on unproven, immature technologies. Because the approach under this option is very different from and offers significant cost and schedule disadvantages in comparison to MOX and MOX/immobilization-based options, it is not likely to be supported by the international community, states, and NGOs.

#5b: Advanced Reactors – Thorium Fuel Cycle

Description: This option eliminates the immobilization (PIP) element of the current baseline option. It dispositions 34 MT of plutonium using a thorium/plutonium or thorium/uranium/plutonium fuel cycle in existing, but modified, light water reactors. Proponents of thorium-based fuels claim that these fuels offer increased proliferation resistance and improved fuel cycle economics over the uranium/plutonium fuel that serves as the current basis for the disposition program. However, the potential for improved proliferation resistance is offset by the production of uranium-233, an isotope potentially useable in nuclear weapons. New facilities that would be constructed include a PDCF and a thorium fuel fabrication facility to disposition 34 MT of plutonium at 3.5 MT/year.

$ 5.4 B Total Cost to Implement * (* in FY 2001 constant dollars)	**FY02**	**FY03**	**FY04**	**FY05**	**FY06**
	$137 M	$55 M	$80 M	$78 M	$100 M
	5-Year Budget Profile *				

Costs and Schedule. The total cost projected to implement this option is approximately $5.4 billion (constant FY 2001 dollars). Initial fabrication of plutonium-containing thorium fuel would occur in FY 2016, and the project would be completed in FY 2027, eight years later than the MOX options. Confidence in PDCF costs is moderate, as described in Option 1a. However, confidence in fuel fabrication and reactor modification costs is low, and these costs may significantly increase as the option is implemented.

Technology Maturity. The maturity of PDCF technology is as described for Option 1a.

Since thorium fuel is not currently in commercial use anywhere in the world, a substantial degree of development and testing would be required before this fuel type could be considered for use in commercial reactors. This is true even for the Korean Thorium-Plutonium Pressurized Water Reactor concept which builds on proven oxide experience with commercial low enriched uranium fuels. Development requirements would increase substantially if fuel burnup were to be doubled as proposed by some proponents, and an advanced fuel cladding material would be required. The Radkowsky Thorium-Fuel Plutonium Incinerator concept would require the most extensive development and testing since it uses a seed and blanket concept with metal rather than oxide fuel and co-extruded fuel and cladding. This concept would require very costly and time consuming development and testing. Extensive safety and environmental review would be required as well to support NRC licensing. It is extremely doubtful that any commercial U.S. utilities would be willing to change to this fuel cycle.

Nonproliferation and Nuclear Material Security. The primary advantage claimed by proponents of thorium fuel is that the thorium fuel cycle produces a more proliferation resistant spent fuel form than either the uranium-plutonium fuel that is the basis for the current program or the low enriched uranium (LEU) fuel currently used in commercial reactors. This claim arises from the fact that less residual plutonium is produced in spent thorium fuel, and the chief fissile by-product of the fuel cycle (uranium-233) though weapons-useable in theory, has never been deployed in any weapons system. Whereas these claims may or may not be correct, the claimed nonproliferation advantages do not necessarily make this option more attractive than MOX. The conclusion that the overall proliferation resistance of spent fuel is enhanced is questionable because the nonproliferation advantage offered by the small amount of this new spent fuel form would be overwhelmed by the vastly greater amount of civilian LEU spent fuel already in existence. Accordingly, there is little incentive to substantially increase the amount of time and money needed to go beyond Spent Fuel Standard. To do so would defer plutonium disposition by several years, and the high degree of technology development coupled with high cost and extended schedule requirements would offset any nonproliferation advantage.

Sensitivities

Budget Impacts. The costs of developing and testing the unproven thorium fuel cycle and of designing constructing and licensing an unprecedented thorium fuel fabrication facility are about the same as some of the more expensive MOX disposition options. However, the costs and schedule are highly uncertain and could increase significantly, causing completion of the program to be extended by several years.

Impact on States and Other DOE Programs. This option would require consideration of many potential sites for development, testing, and construction of fuel fabrication and testing facilities. Because SRS, the designated site for the PDCF, MOX FFF, and PIP in the current program, might not be selected for all or some of the new activities and facilities, this option might result in a decrease in expected SRS-related employment. Utilities owning the commercial nuclear power reactors needed for this option would likely not be interested in participating due to the cost and schedule uncertainties related to technology development. As a result, this option could jeopardize DOE's commitments to the States of Colorado and South Carolina to remove plutonium from Rocky Flats (to allow site closure by 2006) and to provide a pathway out of the site for plutonium brought to SRS for disposition.

Public and NGO Response. This option does not preserve the elements of DOE's 1997 and 2000 Records of Decision for plutonium disposition. Additional NEPA review and associated opportunities for public involvement would be required. Elimination of immobilization would likely further increase opposition to this reactor option by certain NGOs that already oppose MOX.

International Factors. International support for this more expensive and lengthy option could be difficult to maintain due to the implied lack of urgency. This option would again more significantly alter the existing U.S.-Russian PMDA, and renegotiation of some of the PMDA terms and milestones would be required. The Russian reaction to a shift towards a thorium fuel cycle is uncertain. Although substituting irradiation for immobilization would appeal to Russia, a shift from proven MOX fuel to the unproven thorium fuel cycle is likely to be viewed by Russia as a reduction of U.S. commitment to disposition surplus plutonium.

Other Factors. Congressional support for a more expensive and lengthy thorium option would likely be difficult to sustain, increasing the risk of further delaying or not completing the plutonium disposition mission.

Assessment

#5b: Advanced Reactors - Thorium Fuel Cycle

The thorium option would disposition plutonium more slowly than any of the MOX or MOX/immobilization options, but its cost, though uncertain, is not much higher. While the thorium option requires more technology development than the MOX-MOX/immobilization options, it nevertheless uses existing reactors and would, therefore, require a less extensive technology development effort than the GT-MHR. The risk of failure or significant delay using this option is high because it depends on immature technologies. Furthermore, because the approach under this option has significant schedule disadvantages in comparison to MOX and MOX/immobilization-based options, it is not likely to be supported by the international community, states, commercial utilities, other DOE programs, and NGOs.

4.4 Immobilization Options

The following discussions present a summary evaluation of each of the two de-coupled immobilization options (De-coupled Option #1a and #1b).

#1a: Immobilize at SRS (13 MT)

Description: This option would immobilize 13 MT of surplus non-pit plutonium The balance of surplus plutonium would be stored indefinitely at Pantex. This option includes only the immobilization (PIP) element from the baseline option. The PIP would process the metal and oxide and incorporate it in a ceramic material at a new facility at SRS, and then surround it with vitrified radioactive high-level waste ("can-in-canister") at the existing SRS Defense Waste Processing Facility (DWPF). Plutonium would be dispositioned at 1.3 MT/year over ten years.

$ 2.0 B Total Cost to Implement * * in FY 2001 constant dollars	FY02	FY03	FY04	FY05	FY06
	$3 M	$1 M	$8 M	$12 M	$21 M
	5-Year Budget Profile *				

Costs and Schedule. The total projected cost to implement this option is approximately $2.0 billion (constant FY 2001 dollars) through the end of the assumed disposition period, in addition to an ongoing annual storage cost of $26 million after that time. The project would be completed by 2024. The costs and schedule for this option are based on a conceptual design for PIP.

Technology Maturity. The PIP technology is currently under development. Demonstrations with plutonium materials and high level waste have not yet been conducted and would need to be performed under this option. The design of the PIP is currently suspended.

Nonproliferation and Nuclear Material Security. The U.S. plutonium disposition mission and parallel Russian disposition effort would not be achieved. The final immobilized plutonium forms would meet the Spent Fuel Standard, but pits remaining in storage would remain in a form highly attractive to potential proliferators. DOE provisions for material protection, control, and accounting (MPC&A) would need to remain in place indefinitely for stored plutonium. As with other disposition options, MPC&A would be used to protect plutonium prior to and during processing.

Sensitivities

Budget Impacts. Of all the disposition options, this option incurs the lowest implementation cost. The near-term costs of this option are lower than any of the MOX options.

Impact on States and Other DOE Programs. South Carolina may oppose this option because it would eliminate the PDCF and MOX FFF, reducing the employment that would be created in South Carolina to support disposition activities. Texas may oppose this option because it would become host to the permanent long-term storage of surplus plutonium pits. This option could facilitate the closure of Rocky Flats in Colorado in 2006 by removing surplus plutonium currently stored there, subject to concurrence by South Carolina to receive the Rocky Flats materials.

Public and NGO Response. This option may raise criticism that DOE and the Administration is cutting back on efforts to disposition surplus weapons plutonium. Anti-nuclear groups would support termination of the MOX irradiation effort and would likely argue in favor of expanded immobilization.

International Factors. This option would renounce the existing U.S.-Russian PMDA because it would provide for disposition of only 13 MT instead of the required 34 MT. Moreover, Russia would almost certainly not agree to amend the Agreement to allow the United States to immobilize more than the 8.4 MT specified in the Agreement since it views immobilization without isotopic degradation as another form of storage. The supply of separated reactor-grade plutonium in the United States is not sufficient to allow degradation of isotopic composition by mixing reactor-grade and weapons-grade plutonium. Most G-7 nations (e.g., Britain, France, Canada, Italy, Japan, etc.) are likely to be confused by the change in U.S. position especially after the United States had long sought their financial participation in assisting Russia with a program based on the PMDA, which provides for both MOX/reactors and immobilization in the United States.

Other Factors. None.

Assessment

#1a: Immobilize at SRS (13 MT)

This option defers most near-term disposition costs and is among the least expensive options in the near-term. However, it does not achieve the U.S. plutonium disposition mission and places the Russian plutonium disposition effort at risk. Russia would have no incentive to complete disposition of its surplus plutonium. It would have limited support internationally and may be opposed by South Carolina and Texas.

#1b: Immobilize at SRS (34 MT)

Description: This option would immobilize all 34 MT of surplus plutonium and includes the immobilization (PIP) and pit conversion (PDCF) elements from the baseline option. The PDCF would convert surplus pits and metal to plutonium oxide and provide the oxide to the PIP. The PIP would process the oxide and incorporate it in a ceramic material at a new facility at SRS, and then surround it with vitrified radioactive high-level waste ("can-in-canister") at the existing SRS DWPF. Plutonium would be dispositioned at 5 MT/year.

$ 3.2 B Total Cost to Implement *	FY02	FY03	FY04	FY05	FY06
	$56 M	$67 M	$41 M	$49 M	$167 M
* in FY 2001 constant dollars	5-Year Budget Profile *				

Costs and Schedule. The total projected cost of this option is approximately $3.2 billion (constant FY 2001 dollars). The project would be completed by FY 2022. The costs and schedule for this option are based on a conceptual design for PIP.

Technology Maturity. The PIP technology is currently under development. Demonstrations with plutonium materials and high level waste have not yet been conducted and would need to be performed under this option. The design of the PIP is currently suspended.

Nonproliferation and Nuclear Material Security. While the U.S. plutonium disposition mission would be achieved, continuing progress in the parallel Russian disposition effort would likely end. The final immobilized plutonium forms produced under this option would meet the Spent Fuel Standard. As with other disposition options, DOE provisions for MPC&A would be needed to protect plutonium prior to and during processing to prevent theft or diversion.

Sensitivities

Budget Impacts. The near-term costs of this option are lower than any of the coupled options, and the implementation cost is lower than the least expensive coupled option (Option 4, Eurofab / U.S. Burn). Compared to the 13 MT immobilization option (de-coupled Option 1a), the PDCF costs incurred under this option are less than the long-term pit storage costs incurred under De-coupled Option 1a, and PIP costs are about the same.

Impact on States and Other DOE Programs. This option would eliminate the MOX FFF, reducing employment that would have been created in South Carolina. This option would facilitate the closure of Rocky Flats in Colorado in 2006 by allowing surplus plutonium currently stored there to be removed.

Public and NGO Response. This option would receive a mixed reaction from the public and NGOs. It is likely to be applauded by anti-nuclear groups and those favoring immobilization over MOX/irradiation. Other groups who believe that MOX/irradiation is a key element needed to achieve disposition of Russian plutonium are likely to criticize this option.

International Factors. This option would almost certainly lead to termination of the existing U.S.-Russian PMDA because Russia views immobilization without isotopic degradation as another form of storage and, thus, would almost certainly not agree to amend the PMDA to allow more immobilization.

The supply of separated reactor-grade plutonium in the United States is not sufficient to allow isotopic degradation by mixing reactor-grade and weapons-grade plutonium. Most G-7 nations (e.g., Britain, France, Canada, Italy, Japan, etc.) are likely to be confused by the change in U.S. position especially after the United States had long sought their financial participation in assisting Russia with a program based on the PMDA, which provides for both MOX/reactors and immobilization.

Other Factors. None.

Assessment

#1b: Immobilize at SRS (34 MT)

This option achieves full disposition of 34 MT of U.S. plutonium inventory with the lowest cost. However, it would almost certainly lead to termination of bilateral plutonium disposition with Russia. Russia would have no incentive to complete disposition of its surplus plutonium. This option would have limited support internationally.

4.5 Storage Options

The following discussions include a summary evaluation of each of the two de-coupled storage options (De-coupled Options #2 and #3).

#2: Store in Place

Description: This option would permanently maintain all 34 MT of surplus plutonium in the form of pits, metals, and oxides at six existing DOE storage sites. This option is equivalent to a "No Action Alternative." Surplus plutonium would not be dispositioned. Storage costs would be incurred for continued management of the material and the upgrading of existing storage sites, as necessary.

$ 4.6 B Total Cost to Implement*	FY02	FY03	FY04	FY05	FY06
	$0 M	$0 M	$23 M	$46 M	$69 M
* in FY 2001 constant dollars	5-Year Budget Profile *				

Costs and Schedule. The total projected implementation cost of this option is $4.6 billion (constant FY 2001 dollars), through the end of the assumed disposition period (i.e., FY 2027), in addition to an ongoing annual storage cost of $246 million ($2.5 billion per decade) after that time. Costs would continue indefinitely because the plutonium would remain undispositioned in its current form. Confidence in storage costs is high, because existing technologies and facilities would continue to be used. (Incremental storage costs for FY 2002 and FY 2003 are zero because these costs are incurred equally for all options).

Technology Maturity. While the technologies for storing plutonium currently in use throughout the complex are considered mature, there is no experience for very long-term storage of pits and non-pit plutonium.

Nonproliferation and Nuclear Material Security. The U.S. plutonium disposition mission and parallel Russian disposition effort would not be achieved. Russian plutonium would remain subject to the increasing risk of theft or diversion. For U.S. plutonium, DOE provisions for MPC&A would need to remain in place indefinitely to maintain fissile material security. The U.S. storage forms would not meet the Spent Fuel Standard and would remain in a form highly attractive to potential proliferators. However, the proliferation risk in the United States is considered to be low.

Sensitivities

Budget Impacts. The $4.6 billion cost for continued storage up to 2027 is as costly as many of the other disposition options. However, in the long-term, this option is more expensive because the plutonium remains in storage indefinitely at a cost of $2.5 billion per decade, and costs for final disposition of surplus plutonium would still need to be incurred.

Impact on States and Other DOE Programs. Both South Carolina and Colorado would strongly oppose this option. South Carolina would view this option as an abrogation of DOE's Record of Decision to construct and operate plutonium disposition facilities at SRS, affecting employment related to those facilities. In Colorado, DOE commitments to close the Rocky Flats Plant by 2006 would not be achieved.

Plutonium storage at Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Idaho National Engineering and Environmental Laboratory, and Hanford Site would also continue indefinitely. Given the dependence of the Texas Panhandle region on agriculture and livestock interests which, in turn, rely on the Ogallala Aquifer for water, the willingness of the State of Texas to become a permanent repository for plutonium pits is uncertain. This option would likely extend indefinitely the plutonium storage missions at SRS and Pantex, managed by the DOE Offices of Environmental Management and Defense Programs.

Public and NGO Response. The public and NGOs would be expected to oppose approaches that depend on continued long-term storage due to proliferation concerns associated with primarily Russian, but also U.S., plutonium. Additionally, continued storage of weapons-grade plutonium at the Rocky Flats Plant would be considered unacceptable.

International Factors. A long-term storage option would renounce the existing U.S.-Russian PMDA. A storage strategy would also be viewed by Russia and the G-7 as a reversal of a long-standing U.S. position advocating the need to disposition surplus inventories of weapons-grade plutonium.

Other Factors. None.

Assessment
#2: Store in Place

This option is more expensive than any of the disposition alternatives when the long-term annual storage costs are taken into account. Costs for final disposition of surplus U.S. plutonium would still need to be incurred. This option does not achieve the U.S. plutonium disposition mission, and it renounces the U.S.-Russian PMDA. Russia would have no incentive to complete disposition of its surplus plutonium. It would represent a reversal of the U.S. position on disposition of surplus plutonium, be derided internationally, and be opposed by states and the public.

#3: Consolidate / Store at Fewer Sites

Description: This option would permanently maintain all 34 MT of surplus plutonium in the form of pits, metals, and oxides. The material would be consolidated, and the number of storage sites would be reduced from six to two. Surplus plutonium would not be dispositioned. Storage costs would be incurred for continued management of the material, material transport during consolidation, construction of new facilities, and the upgrading of existing storage sites, as necessary.

$ 3.5 B	**FY02**	**FY03**	**FY04**	**FY05**	**FY06**
Total Cost to Implement *	$ 0	$0	$ 0	$53	$79
* in FY 2001 constant dollars	**5-Year Budget Profile ***				

Costs and Schedule. The total projected cost to implement this option is approximately $3.5 billion (constant FY 2001 dollars), through the end of the assumed disposition period (i.e., FY 2027), in addition to an ongoing annual storage cost of $105 million ($1.0 billion per decade) after that time. Costs would continue indefinitely because the plutonium would remain undispositioned. Confidence in storage costs is high, because existing technologies and facilities would continue to be used. (Incremental storage costs for FY 2002, FY 2003, and FY 2004 are zero because these costs are incurred equally for all options).

Technology Maturity. The technologies that would be used under this option are the same as those used in the Store-in-Place option. While the technologies for storing plutonium currently in use throughout the complex are considered mature, there is no experience for very long-term storage of pits and non-pit plutonium.

Nonproliferation and Nuclear Material Security. The nonproliferation and nuclear materials security issues under this option are similar to those for the Store-in-Place option. The U.S. plutonium disposition mission and parallel Russian disposition effort would not be achieved. Russian plutonium would remain subject to the increasing risk of theft or diversion. For U.S. plutonium, DOE provisions for MPC&A would need to remain in place indefinitely to maintain fissile material security. The U.S. storage forms would not meet the Spent Fuel Standard and would remain in a form highly attractive to potential proliferators. However, the proliferation risk in the United States is considered to be low.

Sensitivities

Budget Impacts. The $3.5 billion cost of this option up to 2027 is less than most of the other disposition options. However, in the long-term, this option is more expensive because the plutonium remains in storage indefinitely at a cost of $1.0 billion per decade, and costs for final disposition of surplus plutonium would still need to be incurred.

Impact on States and Other DOE Programs. South Carolina would view this option as a failure to provide a pathway out of SRS for surplus plutonium brought there for disposition (assuming that SRS was selected as one of the consolidation sites). Therefore, this option can be expected to be strongly opposed by the State of South Carolina and challenged in the courts. This option would likely require additional NEPA review and public meetings. Given the dependence of the Texas Panhandle region on agriculture and livestock interests which, in turn, rely on the Ogallala Aquifer for water, the willingness of the State of Texas to become a permanent repository for plutonium pits is uncertain. This option would likely extend indefinitely the plutonium storage missions at SRS and Pantex, managed by the Offices of Environmental Management and Defense Programs.

Public and NGO Response. The public and NGOs would be expected to oppose this option because it is a significant departure from DOE's current decisions and commitments and because it depends on continued long-term storage due to proliferation concerns associated with primarily Russian, but also U.S., plutonium.

International Factors. A long-term storage option would renounce the existing U.S.-Russian PMDA. A storage strategy would also be viewed by Russia and the G-7 as a reversal of a long-standing U.S. position advocating the need to disposition surplus inventories of weapons-grade plutonium.

Other Factors. None.

Assessment
#3: Consolidate / Store at Fewer Sites

This option does not achieve the U.S. plutonium disposition mission and it renounces the U.S.-Russian PMDA. Costs for final disposition of surplus U.S. plutonium would still need to be incurred. Russia would have no incentive to complete disposition of its surplus plutonium. This option would represent a reversal of the U.S. position on disposition of surplus plutonium, be derided internationally, and be opposed by states and the public. It is highly improbable that a suitable location for a consolidated storage facility can be established within the foreseeable future.

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5. Preferred Option for U.S. Plutonium Disposition

5.1 Introduction

This chapter identifies the preferred option for the U.S. Plutonium Disposition Program based on the Administration's concerns and DOE's evaluation of the range of options considered. DOE's conclusion for the U.S. plutonium disposition program, based on the analysis presented in this report, is as follows:

- Option 3a—MOX Only with High Quality Pu-Some PIP Material Purified at Enhanced MOX FFF—is the most advantageous and should be pursued as the preferred option.

The basis for this conclusion is summarized in this chapter, and information regarding cost and schedule for this preferred option is presented.

5.2 Comparison of Options

To compare the various U.S. options, the option groupings are first considered: Storage, Immobilization, Advanced Reactors, and MOX disposition. Table 5-1 lists the options according to these groups with information on the projected cost to implement and completion date of each option.

Table 5-1. Summary of Costs and Schedules for U.S. Options

Option Grouping		Option	Cost to Implement [a,b] (Billion FY 2001 Constant $)	Irradiation Completion Date	Immobilization Completion Date
Coupled Options					
MOX (6)	1a.	Project Baseline – One-Year Delay [in the Start of Construction of the MOX FFF] from Cost Report	5.4	FY 2020	FY 2020
	1b.	Project Baseline with Accelerated MOX Throughput	4.6	FY 2016	FY 2020
	2.	MOX with 34 MT Pu – All PIP Mat'l Purified at F-Canyon	5.0 [c]	FY 2019	n/a
	3a.	MOX Only with High-Quality Pu – Some PIP Mat'l Purified at Enhanced MOX FFF	3.8	FY 2019	n/a
	3b.	MOX Only with High-Quality Pu – Some PIP Mat'l Purified at F-Canyon	4.0 [c]	FY 2019	n/a
	4.	Eurofab / U.S. Burn	3.3 [d]	FY 2022	n/a
Advanced Reactors (2)	5a.	Advanced Reactors – GT-MHR	6.1 [e]	FY 2032	n/a
	5b.	Advanced Reactors – Thorium Fuel Cycle	5.4 [f]	FY 2027	n/a
De-Coupled Options					
Immobilization (2)	1a.	Immobilize at SRS (13 MT); Store Pits Indefinitely	2.0 [g]	n/a	FY 2023
	1b.	Immobilize at SRS (34 MT)	3.2	n/a	FY 2021
Storage (2)	2.	Store in Place	4.6 [h]	n/a	n/a
	3.	Consolidate / Store at Fewer Sites	3.5 [i]	n/a	n/a

[a] Costs for all options include research and development, pre-capital, design and construction of facilities and capital equipment, operations, deactivation, MOX and HEU fuel credits (where applicable), and contingency. Costs exclude pre-FY 2002 costs and pre-disposition interim storage costs that would be incurred under any of the disposition options.

[b] For all coupled options and de-coupled Option #1b**,** Pit Disassembly and Conversion Facility (PDCF) operating costs include PDCF-specific safeguards and security and pit packaging activities.

[c] For F-Area facilities costs for coupled Options 2 and 3b, operating costs partially cover surveillance and maintenance of F-Canyon but do not cover life-extension upgrades, and deactivation costs are excluded. Sharing of operating costs with other DOE program elements is assumed.
[d] For coupled Option 4, assumptions include: 1) The PIP and MOX FFF would be eliminated. 2) The PDCF would convert all pit and non-pit materials to plutonium oxide feed material for fabrication of MOX fuel in a European facility.
[e] For coupled Option 5a, assumptions include: 1) Costs include an optimistic $9 billion in anticipated revenue recovery and residual reactor value. 2) The PIP and MOX FFF would be eliminated. 3) The PDCF would convert all pit and non-pit materials to plutonium oxide feed material. 4) A new fuel fabrication facility would be required. 5) Three new reactor plants including 12 reactor modules would be constructed. 6) Extensive reactor design development, component development and testing, and code development would be required.
[f] For coupled Option 5b, assumptions include: 1) The PIP would be eliminated. 2) The PDCF would convert all pit and non-pit materials to plutonium oxide feed material for the thorium fuel fabrication facility, and the PDCF would perform aqueous polishing. 3) Substantial thorium fuel development and testing would be required. 4) Fuel fabrication process and equipment development would be required. 5) New analytical codes and a more extensive lead (fuel) test assembly program would be required.
[g] For de-coupled Option 1a: 1) The cost does not include an annual storage cost of $26 million to indefinitely store the pit material at Pantex. 2) Because 13 MT of non-pit plutonium currently stored at Rocky Flats, Hanford, SRS, LANL, and LLNL would be immobilized, no incremental costs for storage of this material is included in this option.
[h] For de-coupled Option 2: 1) The cost does not include an annual storage cost of $246 million that would continue to occur after the end of the assumed disposition period (i.e., FY 2027). This cost would continue indefinitely because the plutonium would remain undispositioned in its current form. 2) It is assumed that no new consolidated storage facility is developed. 3) Facility upgrade costs are included as applicable. 4) This option includes storage costs for Pantex, Rocky Flats, Hanford, SRS, LANL, and LLNL.
[i] For de-coupled Option 3, the cost does not include an annual storage cost of $105 million that would continue to occur after the end of the assumed disposition period (i.e., FY 2027). This cost would continue indefinitely because the plutonium would remain undispositioned in its current form.

5.2.1 U.S. Option Categories

5.2.1.1 Storage

Two variations were presented for this analysis, storing the plutonium in place and storing at fewer sites.

Cost. The storage options are more expensive than immobilization and have costs similar to the MOX options. Near term costs (through FY 2006) are lower than the MOX options. Long-term costs are expected to be substantially higher.

Engages Russian Interest & Commitment. The long-term storage of surplus U.S plutonium is categorized as a “de-coupled” option since it would renounce the 2000 U.S.-Russian PMDA and would likely put an end to Russian efforts to dispose of surplus Russian plutonium. Renouncing the PMDA is also likely to have negative secondary impacts on key aspects of other U.S.-Russian nonproliferation programs, such as monitoring and inspection of the Mayak Fissile Material Storage Facility, the Trilateral Initiative, and cooperation on Materials Protection and Control efforts.

Domestic and International Commitments. Storage in place undercuts existing commitments to the states, particularly South Carolina, which is counting on disposition as a means to avoid becoming the permanent “dumping ground” for surplus weapons-grade plutonium by providing a pathway out of the site for plutonium brought there for disposition. At the same time, disposition is very important to the State of Colorado because it enables shipment of surplus plutonium from the Denver metropolitan area (site of the Rocky Flats Plant) to the Savannah River Site (SRS) and the subsequent closure of Rocky Flats by 2006. Disposition also enables the shipment of surplus plutonium from Idaho National Engineering and Environmental Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Hanford Site to SRS, thereby reducing costs, facilitating site cleanup, and improving security by reducing the number of sites where surplus plutonium is stored. Further, discussions would need to take place with the states of South Carolina and Texas which would likely be the respective consolidated storage sites for inventories of surplus plutonium in non-pit and pit form. At the same time, the other G-7 countries and the European Union, some who have contributed financially to the Russian plutonium disposition program, would view long-term or permanent storage as a broken commitment made by the United States to disposition its own plutonium and support Russian efforts to do so likewise.

U.S. Nonproliferation and Security Objectives. Renouncing the current agreement with Russia to reduce stockpiles of surplus plutonium harms U.S. nonproliferation and security objectives. While the likelihood of theft or diversion of plutonium from secure U.S. storage is extremely low, an important opportunity to reduce stockpiles of plutonium in Russia, where the threat of inside or outside diversion of material is much greater, would be missed.

Conclusion

Long-term storage of surplus U.S. plutonium offers a near-term cost advantage over MOX disposition, but creates a long-term mortgage and significant problems and delays in DOE site closure and cleanup plans, calls into question U.S. credibility internationally, and forfeits an important opportunity to dispose of surplus Russian plutonium.

5.2.1.2 Immobilization

Two variations were presented for this analysis: immobilization of 13 metric tons (MT) of impure, non-pit plutonium and immobilization of 34 MT of plutonium (both pit and non-pit).

Cost. Cost estimates for these options are $2.0 billion and $3.2 billion respectively, considerably less than the project baseline of $5.4 billion involving both MOX/irradiation and immobilization. However, immobilization is not a proven technology on a production-scale basis, so confidence in these cost estimates is somewhat lower than for MOX, which is an industrially proven technology.

Engages Russian Interest & Commitment. Both immobilization options are categorized as "de-coupled" options. The Russians do not consider immobilization to be an acceptable technology for the majority of the disposition program because it does not isotopically degrade the plutonium as does irradiation of MOX fuel in a reactor. The Russians argue that, in the event of a breakout scenario between the two countries, the United States could recapture its weapons-grade plutonium from the immobilized waste form. Further, immobilization is unacceptable to the Russians because it fails to capture the energy content of the plutonium. While Russia has agreed that the United States can immobilize its impure plutonium (approximately 25% of the 34 MT), Russia is unwilling to proceed if the United States fails to irradiate its surplus plutonium as MOX fuel for the majority of its weapons-grade plutonium. As a result, either immobilization option, by itself, would renounce the existing plutonium disposition agreement with Russia.

Domestic and International Commitments. Both immobilization options would provide a pathway out of SRS for plutonium brought there for disposition. Of the two options, South Carolina might prefer the 34 MT variant because it would result in a greater number of job opportunities from building two new facilities (i.e., Pit Disassembly and Conversion Facility (PDCF) and Plutonium Immobilization Plant (PIP)) required to dispose of both pit and non-pit plutonium. There is uncertainty, however, about the willingness of the State of Texas to serve as the long-term repository for surplus pits. This option would terminate the existing U.S.-Russian PMDA because of Russia's views that immobilization is another form of storage. G-7 countries (other than Germany) that have pledged financial support for the Russian program would view this as a broken U.S. commitment.

U.S. Nonproliferation and Security Objectives. As in the case of the storage options, renouncing the existing agreement with Russia to reduce stockpiles of surplus plutonium harms U.S. nonproliferation and security objectives. While the likelihood of theft or diversion of plutonium from secure U.S. storage is considered to be extremely low, an important opportunity to reduce stockpiles of plutonium in Russia, where the threat of inside or outside diversion of material is much greater, would be missed.

Conclusion

While the initial cost estimates of the immobilization options are lower than the baseline, the level of confidence given to technologies in this stage of development is less than that of MOX, which could significantly increase the total cost of this option over time. If the United States were to pursue this option, the U.S.-Russian PMDA would be renounced, as well as the U.S. understandings with the other G-7 nations and possibly some states and DOE sites. Pursuing an immobilization-only option in the United States provides no assurance of what Russia would do with their surplus material.

5.2.1.3 Advanced Reactors

Two variations were examined for this analysis: the gas turbine-modular helium reactor (GT-MHR), and the irradiation of thorium fuel in existing, but modified, light water reactors. DOE's 1995 *Summary Report of the Screening Process to Determine Reasonable Alternatives for Long-Term Storage and Disposition of Weapons-Usable Fissile Materials* eliminated the use of modular helium reactors because of technical immaturity. The 2001 update of the Screening Report (Appendix A) also eliminated this option from consideration, again because of technical immaturity. This analysis considers the GT-MHR in order to provide information for decision-makers on the details and feasibility of this option.

Costs. The costs of developing, testing, and constructing the GT-MHR and associated fuel fabrication facility exceeds the cost of the MOX options. The estimated GT-MHR cost ($6.1 billion) includes nearly $9 billion in revenue recovery and residual value which is assumed to be recovered upon completion of the mission. Almost all of the revenue occurs after 2020. The GT-MHR option would not only require the construction of a new fuel fabrication facility (as in the current program), but it would also require the construction of 12 new reactor modules. Given the extensive development and testing required for the GT-MHR, the disposition schedule would be substantially longer than the current MOX/existing reactor option. For the thorium fuel cycle, the cost of developing, testing, designing, constructing, and licensing an unprecedented thorium fuel fabrication facility is highly uncertain. However, the overall cost of the option is currently estimated to be about the same as implementing the MOX/immobilization baseline. Given the extensive development and testing required, the schedule for the thorium option would also be substantially longer than the current MOX option. Support for either of the highly uncertain, likely expensive, and lengthy advanced reactor options would be difficult to maintain.

Engages Russian Interest & Commitment. Senior Minatom officials have indicated that they do not consider either of these two-advanced reactor options suitable for disposing of surplus plutonium. The Russians would, however, be interested in a long-term U.S.-financed research and development program between the two countries aimed at developing these technologies. The Russians believe that both of these options are technologically immature, costly, and would take considerably more time to dispose of the plutonium than the existing program.

Domestic and International Commitments. For both the GT-MHR and thorium fuel cycle options, the risk of failure or significant delay using these options is high because they depend on unproven and immature technologies. Both domestic and international support would be difficult to maintain because of the longer schedule and implied lack of urgency. Further, neither of these two technologies offers the promise of providing a near-term pathway out of SRS for plutonium brought there for disposition. As a result, the State of South Carolina would likely try to legally enjoin DOE from shipping surplus plutonium from Rocky Flats to SRS, resulting in an inability to close Rocky Flats by 2006.

U.S. Nonproliferation and Security Objectives. The thorium fuel cycle would produce quantities of uranium-233 in the spent fuel which is easily separable and is usable in nuclear weapons. One option for reducing this risk is to add uranium-238 to the fuel. However, this results in the production of additional amounts of plutonium. It also results in a unique fuel metallurgy (i.e., thorium, uranium and plutonium) that has never been qualified before. For the GT-MHR, even though a greater amount of plutonium is destroyed, the extended and uncertain schedule for this option offsets this advantage.

Conclusion

The advanced reactor options' apparent excessive and uncertain costs, elongated schedules, technical immaturity, and questionable successful outcome offer no advantage over the current baseline program.

5.2.1.4 MOX Disposition

Six variations of the MOX/irradiation approach were examined in this analysis. Two options involve the use of both MOX/irradiation and immobilization, and the remaining four options are based solely on the irradiation of MOX fuel. Of the four MOX-only options, three options involve producing MOX fuel in the United States, and the final option involves producing MOX fuel at commercial European facilities.

Cost. The costs to implement the six MOX options fall within a range between $3.3 and $5.4 billion. These options are less costly than the advanced reactor options but more costly than the immobilization options. MOX options have the highest near-term (through FY 2006) costs. The confidence in the MOX option costs, which are based on the results of several years of design and development, is relatively high. In particular, the proposed MOX technology has been commercially developed and is in use in several countries worldwide. Finally, the MOX approach allows the disposition mission to conclude sooner than other (storage and advanced reactor) approaches.

Engages Russian Interest & Commitment. The Russians have long insisted that a bilateral plutonium disposition program with the United States must be based on the irradiation of the plutonium. As a result, the September 2000 U.S.-Russian PMDA requires the United States to disposition 75% of its surplus weapons-grade plutonium (25.6 MT of pits and clean metal) by irradiating it as MOX fuel with immobilization to be used for the remainder (8.4 MT of impure plutonium). Russia, on the other hand, would disposition all of its plutonium by irradiating it as MOX fuel in reactors.

Domestic and International Commitments. All of the MOX options provide a pathway out of SRS for plutonium brought to the site for disposition. As a result, all of the MOX options, including those linked with immobilization, would facilitate the closure of the Rocky Flats Plant by 2006. It would be expected that the State of South Carolina would prefer those options providing the greatest assurance that surplus plutonium would exit the site and those options providing the greatest number of job opportunities. Options 1a and 1b would satisfy both of these criteria because they utilize two technologies for plutonium disposition—allowing each to serve as a backup in the event of unforeseen problems with implementation of the other—and they would result in the construction of three separate facilities (i.e., PDCF, MOX FFF, and PIP). Additional National Environmental Policy Act (NEPA) review would likely be required for any of the MOX-only options since each of these involves the use of different facilities, processes, disposition throughputs, floor space requirements, waste stream volumes, etc., resulting in different environmental circumstances. International consequences from proceeding with a MOX-based approach are better than what would occur under any other approach. Because deviating from a MOX-based approach in the United States would likely cause the Russian disposition effort to stall, the international community is generally supportive of the current MOX program. Countries that have contributed and supported the Russian effort based on U.S. leadership and credibility are likely to continue supporting a U.S. MOX-based approach.

U.S. Nonproliferation and Security Objectives. All of the MOX-only as well as MOX/immobilization options convert plutonium to a form which is practically irretrievable for use in weapons by a potential proliferant. A fundamental underlying objective of the U.S. disposition program is to cause implementation of a parallel disposition effort in Russia. A MOX-based approach in the United States would continue the Russian disposition effort.

Conclusion

MOX is the most advantageous approach to disposition U.S. surplus plutonium (Table 5-2). The costs are reasonable and well understood. The approach has been accepted by Russia and serves as a basis for ongoing progress by Russia and G-7 countries. MOX approaches also meet domestic agreements and commitments with states and match U.S. policy statements for plutonium disposition. Finally, MOX is the only promising approach to advancing the Russian plutonium disposition effort.

Table 5-2. Comparison of U.S. Option Groups

<u>Key</u> ●—More Advantageous ◑—Neutral ○—Less Advantageous	Cost Range (Billion FY2001 Dollars)	Engages Russian Interest & Commitment	Domestic Commitments	International & Nonproliferation Objectives
MOX	3.3 – 5.4	●	●	●
Advanced Reactors	5.4 – 6.1	○	○	○
Immobilization	2.0 – 3.2	○	◑	○
Storage	3.5 – 4.6 [a]	○	○	○

[a] Plus long-term storage costs.

5.2.2 Selecting the Best MOX Option

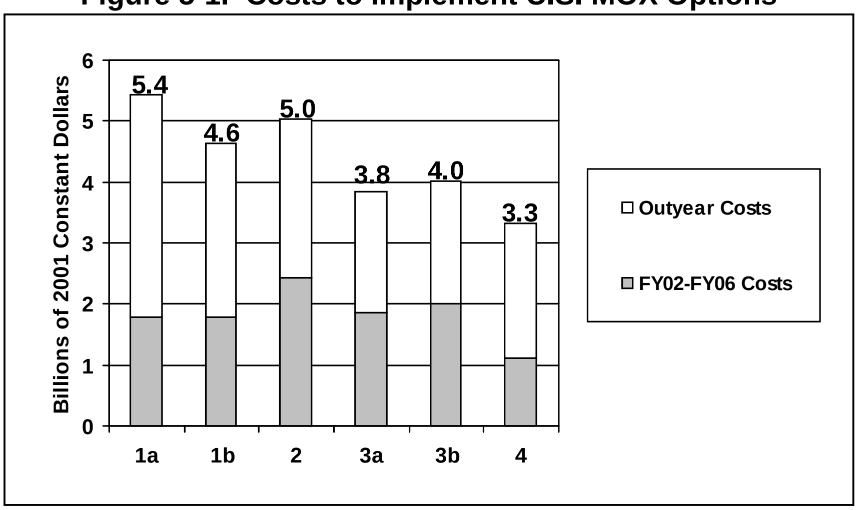
While several characteristics differentiate among the six MOX options examined, these options are also very similar. In particular, all MOX options are "coupled" to the Russian disposition effort and have the advantage of advancing the Russian plutonium disposition effort. Additionally, all MOX approaches depend on reasonably mature technologies and have high prospects of technical success.

The MOX options can be differentiated on the basis of two factors: first, whether they contain an immobilization component and, second, which facilities, disposition schedule, and material inventories they involve. These factors affect how each option ranks against the concerns expressed by the Administration. In particular, they affect the overall cost of each option, the degree of Russian engagement, the impacts on existing commitments to states, and the nonproliferation and security consequences. Based on these factors, Option 3a, MOX Only with High-Quality Pu-Some Material

Purified at Enhanced MOX FFF, is the most advantageous to the United States. The basis for this conclusion is summarized below.

Cost. The costs to implement the MOX options range between $3.3 and $5.4 billion in constant FY 2001 dollars (Figure 5-1). The least expensive option is Option 4 (Eurofab / U.S. Burn). However, the projected cost of this option is highly uncertain. The cost, schedule, and viability of international fabrication of MOX from weapons-grade plutonium are less certain than for domestic fabrication. The actual costs charged by the fabricators vary widely, and the schedule for fabrication and irradiation would be dependent on an unprecedented number of international shipments of weapons-grade plutonium. The next least expensive option is Option 3a (MOX Only with High Quality Pu – Some PIP Material Purified at Enhanced MOX FFF). Three factors contribute to the low cost and relatively high confidence in the costs associated with Option 3a. First, Option 3a substitutes a minor expansion of the MOX infrastructure for the more costly immobilization infrastructure used in Options 1a and 1b. Second, Option 3a avoids the cost and technical complexity associated with purification of difficult-to-process low quality plutonium that would occur under Option 2. Instead, the difficult-to-process material (~2 MT) is replaced at a later time with clean, high quality material that can be less expensively processed into MOX fuel. Third, Option 3a avoids the likely lawsuits and adverse political consequences and highly uncertain costs associated with a large number of international shipments and processing of weapons-grade plutonium (Option 4). Option 3b is the next least expensive option, but its costs are rather uncertain due to the uncertainty in costs associated with adapting the 40-year-old F-Canyon facilities to a new mission, upgrading them to meet current standards, and continuing to operate them for several more years. In particular, the extent to which these costs would be shared by other DOE program elements is not known, and if those elements were to assume a smaller share than assumed in this analysis, the projected $4.0 billion cost to implement Option 3b would increase. The remaining options (Options 1a, 1b, and 2) are significantly more costly.

Figure 5-1. Costs to Implement U.S. MOX Options



Engages Russian Interest & Commitment. Russia has made the use of MOX fuel by the U.S. disposition program a condition for proceeding to disposition surplus Russian plutonium in parallel. Therefore, Russia would likely support any of the MOX options. Given the Russian concern with immobilization, it is likely that Russia would be more receptive to an approach dependent solely on MOX (Options 2, 3a, 3b, and 4). Of these options, 3a and 3b would require additional pure plutonium (available only from future surplus declarations) to substitute for the difficult-to-process material. Russia may have a minor concern that about 2 MT of material would need to come from future declarations. However, this concern is not likely to be significant since the last 2 MT of material would not be required for about 15 years, and the current nuclear disarmament trends indicate that additional surplus material is possible.

Domestic and International Commitments. The three most important domestic commitments that would be affected by plutonium disposition are (1) providing a pathway for the eventual removal of plutonium brought to SRS for disposition; (2) shipment of the remaining non-pit plutonium from Rocky Flats to SRS, allowing the closure of Rocky Flats in 2006; and (3) the 1997 and 2000 Records of Decision that decide on and support the dual-track MOX/immobilization strategy for disposition of surplus plutonium. All the MOX options support the first two of these commitments. However, only the two MOX options containing an immobilization component (Option 1a, Project Baseline, and Option 1b, Project Baseline with Accelerated MOX Throughput) support the third commitment. All other MOX options would likely require additional NEPA review and changes to the standing program decisions made in 1997 and 2000. While elimination of the present dual-track strategy containing an immobilization component (Options 1a and 1b) would be opposed by some NGOs, one of the principal arguments in favor of the dual-track approach—increased flexibility and timely disposition—is less valid today since many of the initial developmental and contractual uncertainties of the MOX program have now been resolved.

International commitments are not a significant discriminator between the MOX options. Schedule adjustments would be required under any of the MOX options. Other G-7 countries have based their contributions to the Russian program, in part, on the PMDA. These contributions also would be supported by any of the MOX options that support the PMDA. As discussed above (under Engages Russian Interest & Commitment), Options 3a and 3b would require a 2 MT substitution of plutonium that would need to be addressed in the PMDA, but, this is not likely to be a significant concern to Russia.

U.S. Nonproliferation and Security Objectives. This factor is only a minor discriminator among the MOX options. All MOX options would support the Russian disposition effort, and all would result in U.S. material meeting the Spent Fuel Standard. However, Option 4 (Eurofab / U.S. Burn) is less favorable under this criterion because it would require an unprecedented series of international plutonium shipments, and the security and vulnerability issues of such an effort have not been fully analyzed.

Conclusion

MOX Option 3a is the most advantageous of the MOX options. Its costs to implement are among the lowest ($3.8 billion) and have a high level of confidence. This option would support continued progress with Russia on plutonium disposition, would have limited domestic and international consequences, and is consistent with U.S. nonproliferation and security objectives. It would require additional environmental review to analyze changed circumstances and to substitute an expansion of the MOX program for the immobilization program in the current Project Baseline.

5.3 Preferred Option Cost and Schedule

The congressional directive requested that, for the preferred option, DOE state the cost of construction and operation of the facilities required, specify a schedule for construction of such facilities, including milestones, specify a schedule for funding the cost of such facilities, and specify the means by which all surplus defense plutonium will be removed from the SRS for storage or disposal elsewhere.

The total projected cost to implement this option is approximately $3.84 billion (constant FY 2001 dollars), distributed as follows: PDCF $1.69 billion and MOX FFF $2.15 billion. The estimated costs to implement the option are shown in Table 5-3.

Table 5-3. Total Projected Cost to Implement Preferred Option by Cost Category: FY 2002 – FY 2020

(thousands of **constant FY 2001** dollars)

Facility Name or Type	Research & Development and Pre-Capital	Design & Construction of Facilities and Equipment Capital	Operations [1]	Deactivation	Contingency	Total
PDCF	249,300	440,900	718,200	9,100	267,700	$1,695,200
MOX FFF	326,800	1,058,200	1,226,800	9,100	497,800	$2,154,500 [2]
TOTAL	**$576,100**	**$1,509,100**	**$1,945,000**	**$18,200**	**$765,500**	**$3,849,700 [2]**

[1] Deactivation is not included in the Operations cost category. For PDCF, operating costs include PDCF-specific safeguards and security and pit packaging activities.

[2] The total Cost to Implement and total MOX FFF cost include MOX (-$733,200) and HEU fuel credits (-$231,000) that are not shown on the table.

The key milestones for implementing this option are listed in Table 5-4.

Table 5-4. Key Milestones

Milestone	Facilities	
	PDCF	MOX FFF
Conceptual design/NEPA	n/a	n/a
Design	FY 1999-2004	FY 1999-2003
NRC licensing	n/a	FY 2000–2005
Long-lead equipment procurement & site preparation	FY 2005 - 2006	FY 2003-2004
Construction	FY 2006 - 2009	FY 2004 - 2007
Startup	FY 2009	FY 2007
First MOX fuel fabricated	n/a	FY 2008
Full-scale operations	FY 2010 - 2017	FY 2007 - 2019
Deactivation	FY 2018	FY 2020

The funding requirements for this preferred option are about $2 billion less than that which would be required for the baseline option described in the March 2001 Cost Report prior to the Administration-directed review. The lower cost is primarily the result of eliminating the PIP and optimizing the design of the PDCF. Reduced operations costs for the MOX FFF and PDCF due to shortened operating lifetimes and an increase in the MOX fuel credit due to increased MOX throughput also contribute to the lower total cost, but these savings are offset by increases associated with increased MOX FFF throughput. Table 5-5 presents the projected annual funding, in constant FY2001 dollars, that would be required to implement this plutonium disposition option over its life cycle. These costs are for U.S. plutonium disposition activities only. Costs for other Office of Fissile Materials Disposition activities are not included.

Table 5-5. Estimated Annual Funding Requirements for Preferred U.S. Plutonium Disposition Option: FY 2002– FY 2020

Facility Name	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011-2020	Total
PDCF	37.0	65.3	32.9	37.4	146.0	274.9	268.9	94.7	98.8	639.3	$1,695.2
MOX FFF	115.0	155.5	417.7	447.9	419.1	237.7	55.2	52.2	19.3	234.9	$2,154.5
TOTAL	**$152.0**	**$220.8**	**$450.6**	**$485.3**	**$565.1**	**$512.6**	**$324.1**	**$146.9**	**$118.1**	**$874.2**	**$3,849.7**

MOX technology has been commercially developed and is in use in several countries worldwide. As a result, there is a high degree of confidence in the costs, which are also based on the several years of design and development efforts in the U.S.

Implementation of the preferred U.S. plutonium disposition option will result in removal from the Savannah River Site of all surplus defense plutonium currently planned for disposition. It will facilitate the closure of the Rocky Flats Plant by 2006 and removal of stored plutonium from other sites around the DOE complex. Selection of this option will require some additional NEPA review to substitute an expansion of the MOX program for the immobilization element in the current Project Baseline. This option will also require the addition of two reactors to the four currently under contract. All surplus defense plutonium brought to SRS for disposition under this option will be removed from SRS in the form of fresh MOX fuel assemblies. These fuel assemblies will be irradiated in commercial nuclear reactors, and the spent fuel that is produced will ultimately be disposed of as part of each reactor's spent fuel disposal program.

Total Fissile Materials Disposition Program funding requirements for FY 2002 through FY 2008, including U.S. plutonium disposition, U.S. highly enriched uranium (HEU) disposition, fissile materials storage, and Russian fissile materials disposition, are shown in Table 5-6. These costs have been adjusted for escalation and are presented in current year dollars.

Table 5-6. Estimated Annual Funding Requirements for Fissile Materials Disposition Program: FY 2002– FY 2008
(millions of **current year escalated** dollars)

Program Area	2002 Approp.	2003	2004	2005	2006	2007	2008
U.S. Plutonium Disposition							
PDCF	37.0	65.3	35.7	41.6	166.4	322.7	325.1
MOX FFF	115.0	155.5	451.5	497.6	477.8	279.1	66.7
PIP	3.0	-	-	-	-	-	-
Subtotal: U.S. Plutonium Disposition	**155.0**	**220.8**	**487.2**	**539.2**	**644.2**	**601.8**	**391.8**
HEU Disposition	50.0	105.0	93.0	95.5	108.3	99.8	83.4
Storage/Other	28.1	24.6	32.4	40.0	41.5	38.9	33.2
Subtotal: U.S. Fissile Materials Disposition Program	**233.1**	**350.4**	**612.6**	**674.7**	**794.0**	**740.4**	**508.5**
Russian Fissile Materials Disposition [a]							
Funds Spent in Russia	6.0	20.0	32.4	44.4	45.6	47.0	48.4
Funds Spent in U.S.	13.0	14.0	16.2	22.2	22.8	23.5	24.2
Subtotal: Russian Fissile Materials Disposition Program	**19.0**	**34.0**	**48.6**	**66.7**	**68.4**	**70.4**	**72.5**
FISSILE MATERIALS DISPOSITION PROGRAM TOTAL	**$252.1**	**$384.4**[b]	**$661.2**	**$741.4**	**$862.4**	**$810.9**	**$581.0**

a. Russian materials disposition funding does not include $200 million previously set aside
b. DOE's FY 2003 budget request to Congress is $384.0 million

5.4 Conclusions

Major improvements in the Plutonium Disposition Program resulting from the Administration-directed review are as follows:

- Total cost to implement the U.S. program has been reduced by about $2 billion, relative to the disposition strategy presented in the March 2001 Cost Report, primarily by replacing the immobilization portion of the program with enhanced MOX capability.
- Peak year funding requirements for the program have been reduced by approximately $500 million by constructing the MOX Fuel Fabrication Facility and the Pit Disassembly and Conversion Facility sequentially.
- The overall U.S. disposition program schedule has been reduced by three years by accelerating the rate at which plutonium is processed.
- Cost and schedule uncertainties have been reduced by focusing the disposition effort on technologies that are more proven than those of the previous program.

The review also has resulted in an option that is responsive to concerns regarding closure of the Rocky Flats Plant by 2006 and that ensures a path forward for removal of surplus defense plutonium brought to the Savannah River Site for disposition. DOE believes that these improvements are responsive to the concerns regarding the program that were expressed by the Administration. Implementation of these improvements will form a sound basis for proceeding with disposal of surplus defense plutonium at the SRS under the U.S.-Russia PMDA.

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