The Mixed Waste Management Facility

Cost-Benefit Analysis for the
Mixed Waste Management Facility at

Lawrence Livermore National Laboratory **RECEIVED**

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

UCRL-ID--123266

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Lawrence Livermore National Laboratory

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Ronald D. Streit, LLNL

April 1996

Lawrence Livermore National Laboratory
University of California • Livermore, California • 94550

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Preface

This report describes the cost-benefit analysis for the Mixed Waste Management Facility at LLNL. The analysis is based on a number of assumptions and deployment options. A set of base assumptions that best represent the "expected case" as developed by the authors has been made. Subsequently, EM-50, the Options Analysis Team, and the Mixed Waste Focus Area reviewed the draft document and provided additional input. To the extent possible, we have incorporated these inputs into the baseline assumptions, or we have addressed them as part of the sensitivity analysis for this study. The input and comments received were well appreciated; they further strengthen the overall findings of this report.

Executive Summary

Introduction

The Mixed Waste Management Facility, or MWMF, has been proposed as a national testbed facility for the demonstration and evaluation of technologies that are alternatives to incineration for the treatment of mixed low-level waste. The facility design will enable evaluation of technologies at pilot scale, including all aspects of the processes, from receiving and feed preparation to the preparation of final forms for disposal. The MWMF will reduce the risk of deploying such technologies by addressing the following:

- Engineering development and scale-up.
- Process integration and activation of the treatment systems.
- Permitting and stakeholder issues.

In light of the severe financial constraints imposed on the DOE and federal programs, DOE/HQ requested a study to assess the cost benefit for the MWMF given other potential alternatives to meet waste treatment needs. The MWMF Project was asked to consider alternatives specifically associated with commercialization and privatization of the DOE site waste treatment operations and the acceptability (or lack of acceptability) of incineration as a waste treatment process. The result of this study will be one of the key elements for a DOE decision on proceeding with the MWMF into Final Design (KD-2) vs. proceeding with other options.

Analysis

We considered a number of scenarios. As one case we commissioned Science Applications International Corporation (SAIC) to complete an independent cost-benefit study for the MWMF (Appendix A). SAIC took a global perspective assessing the cost benefit of using the MWMF to promote competition in the waste treatment industry. We have expanded on this study by incorporating scenarios using different technologies and the benefit derived from each technology.

In addition to this analysis, we have identified a number of more specific case scenarios that provide an alternative approach to estimating the MWMF return-on-investment (ROI). These are based on varying assumptions as to the cost of demonstrating new treatment technologies, how many technologies are to be demonstrated, where the technologies that are successfully demonstrated are deployed, and, ultimately, the cost of building and operating non-incineration treatment facilities. These cases are summarized below.

Case 1—Should DOE do technology demonstrations?

This case considers the cost associated with commercial deployment of treatment facilities with and without prior integrated pilot-scale demonstrations of the processes.

Case 2—Should DOE demonstrations occur at the MWMF or complexwide?

This case studies the use of the MWMF as a centralized demonstration facility vs. DOE demonstrations at various sites throughout the complex or, equivalently, independent private industry demonstrations.

We evaluated Cases 1 and 2 for both the situation in which technologies are to be deployed at DOE facilities within the four "non-incineration states," and for the more general case for deployment DOE complexwide. This second situation assumes that all incinerators throughout the DOE complex are no longer viable for the treatment of mixed waste.

Case 3—What if all waste could be incinerated?

This case compares the deployment of non-incineration technologies to the option of shipping the respective waste streams to incinerator facilities out of state.

Results and Conclusions

Although the approaches taken to calculate the net cost benefit in each of the scenarios described above are very different, in all but the last, very special, case there is a net benefit for the construction and use of the MWMF as a centralized, integrated demonstration facility for evaluating technologies. Table 1 summarizes the net benefit for each case. The range shown in the two data columns is attributed to inputs received from EM-50, the Mixed Waste Focus Area (MWFA), and the representatives of the Options Analysis Team who discussed the ranges for the benefit and costs associated with demonstrations and facility construction. On balance, the net present value is on the order of \$100M, with an annual internal rate of return ranging from a few percent to almost 90%.

In general, a few key conclusions can be drawn:

1. Significant cost reductions will result from promoting competition in the mixed waste treatment community (SAIC results and subsequent analysis).
2. Significant cost advantage will result from the DOE conducting pilot-scale demonstrations prior to deploying full-scale facilities (Case 1).
3. Significant cost benefit will result from consolidating pilot-scale demonstrations to make maximum benefit of available resources and expertise at a single site (Case 2).

4. The benefits for MWMF demonstrations are greatly enhanced if the option for using incinerators is curtailed DOE complexwide and new alternative processes are used to meet the complexwide waste treatment needs (Cases 1b and 2b).
5. The benefit of demonstrating new technologies or deploying additional waste processing capacity anywhere in the complex is greatly reduced if (1) shipping all waste to incinerator states is viable, (2) there will not be a need to have options for treating waste at or near the site of generation for current inventory or future continuing operations, and (3) additional incinerator capacity will not be required (Case 3).

In reality, many of the cost benefits described in this report are cumulative. The general benefits will in most cases be combined with the additional specific case benefits. For instance, the cost benefit of increasing competition and thus reducing the cost for treatment does not preclude the cost benefit of consolidating treatment demonstrations into a single integrated facility. Similarly, the cost savings resulting from the reduction of contingency for plant construction occur even if we also improve operational efficiencies. As such, the benefits described are conservative and do not convey the full benefit potentially realized.

Table 1. Comparison of cost benefit analysis results for the Mixed Waste Management Facility for various scenarios evaluated.

	Description	Net present value (5% discount rate)	Internal rate of return (annual)
	Global analysis based on reduction of processing cost due to increased competition, process improvements, and expanded processing capability.	\$85M (\$5)–174M	17% 4–25%
Case 1a	Commercial deployment of non-incineration technologies based on a contingency analysis (risk) of MWMF demonstrated systems vs. deployment from current bench-scale development for waste processing needs in the four non-incineration states.	\$210M \$130–280M	44% 30–54%
Case 1b	Commercial deployment of non-incineration technologies based on a contingency analysis (risk) of MWMF demonstrated systems vs. deployment from current bench-scale development for waste processing needs throughout the DOE complex. (Expanded Case 1a)	\$968M \$651–1185M	78% 64–88%
Case 1c	Commercial deployment of non-incineration technologies based on estimated improvements in process start-up and operations resulting from pilot-scale demonstrations.	\$64M (\$38)–121M	10% 2–13%
Case 2a	MWMF vs. independent pilot-scale demonstrations specifically orientated to meeting waste processing needs in the four non-incineration states.	\$92M \$29–95M	50% 21–51%
Case 2b	MWMF vs. independent pilot-scale demonstrations specifically orientated to meeting waste processing needs throughout the DOE complex. (Expanded Case 2a)	\$140M \$46–144M	55% 24–56%

		Cost difference between options	
Case 3	Deployment of incineration alternative technologies vs. shipment of all incinerable waste to <i>existing</i> incinerators.	(\$1205M)	

1.0 Introduction

The Mixed Waste Management Facility, MWMF, has been proposed as a national testbed facility for the demonstration and evaluation of technologies that are alternatives to incineration for the treatment of mixed low-level waste. The facility design will enable evaluation of technologies at pilot scale, including all aspects of the processes, from receiving and feed preparation to the preparation of final forms for disposal. The MWMF will reduce the risk of deploying such technologies by addressing the following:

- Engineering development and scale-up.
- Process integration and activation of the treatment systems.
- Permitting and stakeholder issues.

In light of the severe financial constraints imposed on the DOE and federal programs, DOE/HQ requested a study to assess the cost benefit for the MWMF given other potential alternatives to meet waste treatment needs. The MWMF Project was asked to consider alternatives specifically associated with commercialization and privatization of the DOE site waste treatment operations and the acceptability (or lack of acceptability) of incineration as a waste treatment process. The result of this study will be one of the key elements for a DOE decision on proceeding with the MWMF into Final Design (KD-2) vs. proceeding with other options.

We took two approaches. First, we commissioned an independent assessment of the MWMF cost benefit by an organization outside of both the MWMF project and LLNL. We selected SAIC to complete this assessment because they have been an active player in the environmental management area, they have successfully undertaken similar cost-benefit studies for waste treatment activities within and outside of the DOE, and they have the ability to meet the tight timeline for the requested study. After receiving their study, we further developed a number of cases based on their model to assess the robustness of their findings, and to incorporate inputs received from the Mixed Waste Focus Area (MWFA) and EM-50. The results of this study are discussed in Section 2.

Our second approach was an in-house evaluation of the cost benefit for a number of specific cases related to independent demonstrations and commercialization. In Section 3, we discuss each of the cases and their respective results. In particular, we address the benefit of integrated pilot-scale demonstrations vs. commercial deployment from the current "bench-scale" level of development. And, given the benefit of pilot-scale demonstrations, we address the additional benefit of consolidating these demonstrations into an integrated testbed facility.

2.0 General Cost-Benefit Analysis for the MWMF at LLNL

To address the return on investment for the MWMF from a global, as well as independent, perspective, we commissioned SAIC to evaluate the cost benefit of commercializing technologies demonstrated in the MWMF vs. maintaining the status quo. Their study (Appendix A) assesses the use of the MWMF to promote competition, thereby reducing the cost of waste treatment while also increasing DOE's waste processing capacity for every new process deployed. SAIC assumes that technology demonstrations nominally take 18 months, and that two out of every three demonstrations will be successful, leading to additional waste treatment capacity. The additional incremental capacity per process is $\sim 5000 \text{ m}^3/\text{yr}$ ($\sim 170,000 \text{ ft}^3/\text{yr}$) starting from an initial capacity of $16,000 \text{ m}^3/\text{yr}$ ($558,000 \text{ ft}^3/\text{yr}$). Additionally, as each new process is added, they also assume that the cost of processing waste will drop by 5% of the current rate as a result of increased competition. The starting rate is set at $\$7000/\text{m}^3$ ($\$200/\text{ft}^3$) based on current industry data. In their study, 12 processes are demonstrated over 20 years resulting in 8 new deployed systems. The bottom line from this study is that the net present value is $\$360\text{M}$ for proceeding with the MWMF (using an annual discount rate of 4.9%).

2.1 Sensitivity Analysis

The SAIC study was completed independent of LLNL and DOE/OAK. And, while their assumptions are based on the data and references provided, the MWFA, Options Analysis Team (OAT), and EM-50, as well as DOE/OAK and the MWMF team, expressed some concern as to the "robustness" of the analysis. To address these concerns, we completed a sensitivity analysis on many of the key parameters. In particular, we addressed limitations on the growth of the industry capacity and the growth increases for each deployed technology. We also addressed reducing the advantages of deploying new technologies by limiting cost reductions for treating mixed waste. Further, because of the near-term interest in meeting the DOE's mixed waste needs, we evaluated only the first 15 years of MWMF operation and nine technology demonstrations (six deployed). This is significantly below the facility design life and capability to demonstrate new systems. Table 2-1 provides a summary of the input parameters and the study results. As shown, a significant cost benefit is still realized even under these more severe assumptions. Net present values and internal rate of return were positive over a broad range of waste processing cost assumptions. In only one case, cost for treatment starting at $\$100/\text{ft}^3$ and decreasing, were the results even neutral. Tables 2-2a through 2-2e provide detail of the analysis and assumptions for these study excursions.

We conducted an additional iteration of the SAIC study to assess the impact of the initial industry capacity being less than that predicted by SAIC. Adjusted industry capacities were defined by DOE/HQ as shown in Table 2-3a. These are based on the "Interim End-State Plan" for treatment processing capacity as developed from the Site Treatment Plans. For this case, the cost for processing waste is set at \$200/ft³. Specific increases in capacity are assumed over the first few years as a result of system deployment currently envisioned, and subsequently capacity increases at the same rate as given in the previous assessment. Overall, industry capacity is significantly below those estimated in Table 2-2 for all study years. As expected, the net return on investment is reduced, but is still positive.

In Table 2-3b, the industry capacity was arbitrarily reduced to 10% of that shown in Table 2-3a, and the cost for processing waste increased to \$400/ft³. This case effectively looks at what the net benefit would be for MWMF demonstrations if the demonstration were only pertinent to 10% of the existing treatment capacity, i.e., if 90% of the existing capacity were unchanged by the introduction of new processing capability. In this case, the net return on investment turns negative as a result of the initial costs for the MWMF and subsequent low treatment rates. By extending this analysis, we found that demonstrations would need to influence the cost of processing waste in ~60% of the "end-state" capacity for break-even.

Table 2-1. Summary of cost benefit analysis based on excursions from the SAIC Study.

Revised SAIC Study assumptions

Cost savings per tech.	5% for first, 3% for second, 1% thereafter
Capacity increase per tech.	10% for first, 7% for second, 5% thereafter
Overall Industry growth	5% for 4 years, 3% for 3 years, 1% thereafter
Annual Operating cost	\$2.5M
Annual Demonstration cost	\$2.6M

Study results

Treatment/Disposal Cost	Net Present Value (\$K)	Internal Rate of Return
\$300/ cu. ft.	\$174,335	25%
\$250/ cu. ft.	\$129,570	21%
\$200/ cu. ft.	\$84,804	17%
\$150/ cu. ft.	\$40,038	12%
\$100/ cu. ft.	(\$4,728)	4%

Table 2-2a. Revised SAIC Study assumptions with waste processing rate equal to \$100/ft³.

FY	New Technology Deployed	Cost Reduction (percent)	Added Capacity (percent)	Industry Growth (percent)	Industry Capacity (cu. ft/6 mo.)	Avg. Cost (per cu. ft.)	Savings (per cu. ft.)	Total Savings (\$M)	Total Annual Savings (\$M)	Annual Costs (\$M)	Annual Cash Flow (\$M)
1996					279,000	\$100	\$0	\$0	\$0	\$13,800	(\$13,800)
				5%	292,950	\$100	\$0	\$0			
1997				5%	307,598	\$100	\$0	\$0	\$0	\$26,200	(\$26,200)
				5%	322,977	\$100	\$0	\$0			
1998				5%	339,126	\$100	\$0	\$0	\$0	\$17,866	(\$17,866)
				5%	356,083	\$100	\$0	\$0			
1999	1			5%	373,887	\$100	\$0	\$0	\$2,150	\$5,166	(\$3,016)
		5%	10%	5%	429,970	\$95	\$5	\$2,150			
2000				5%	451,468	\$95	\$5	\$2,257	\$4,628	\$5,166	(\$538)
	2			5%	474,042	\$95	\$5	\$2,370			
2001		3%	7%	3%	521,446	\$92	\$8	\$4,093	\$8,309	\$5,166	\$3,143
				3%	537,089	\$92	\$8	\$4,216			
2002				3%	553,202	\$92	\$8	\$4,343	\$8,816	\$5,166	\$3,650
				3%	569,798	\$92	\$8	\$4,473			
2003				3%	586,892	\$92	\$8	\$4,607	\$9,352	\$5,166	\$4,186
	3			3%	604,499	\$92	\$8	\$4,745			
2004		1%	5%	1%	640,768	\$91	\$9	\$5,621	\$11,297	\$5,166	\$6,131
				1%	647,176	\$91	\$9	\$5,677			
2005	4			1%	653,648	\$91	\$9	\$5,733	\$12,443	\$5,166	\$7,277
		1%	5%	1%	692,867	\$90	\$10	\$6,710			
2006				1%	699,795	\$90	\$10	\$6,777	\$13,621	\$5,166	\$8,455
				1%	706,793	\$90	\$10	\$6,844			
2007				1%	713,861	\$90	\$10	\$6,913	\$13,895	\$5,166	\$8,729
				1%	721,000	\$90	\$10	\$6,982			
2008	5			1%	728,210	\$90	\$10	\$7,052	\$15,224	\$5,166	\$10,058
		1%	5%	1%	771,903	\$89	\$11	\$8,172			
2009				1%	779,622	\$89	\$11	\$8,254	\$16,590	\$5,166	\$11,424
	6			1%	787,418	\$89	\$11	\$8,336			
2010		1%	5%	1%	834,663	\$89	\$11	\$9,583	\$19,261	\$5,166	\$14,095
				1%	843,009	\$89	\$11	\$9,679			
2011				1%	851,440	\$89	\$11	\$9,775	\$19,649	\$5,166	\$14,483
				1%	859,954	\$89	\$11	\$9,873			
Net Present Value											(\$4,728)
Internal Rate of Return											4%

Table 2-2b. Revised SAIC Study assumptions with waste processing rate equal to \$150/ft³.

FY	New Technology Deployed	Cost Reduction (percent)	Added Capacity (percent)	Industry Growth (percent)	Industry Capacity (cu. ft/6 mo.)	Avg. Cost (per cu. ft.)	Savings (per cu. ft.)	Total Savings (\$M)	Total Annual Savings (\$M)	Annual Costs (\$M)	Annual Cash Flow (\$M)
1996					279,000	\$150	\$0	\$0	\$0	\$13,800	(\$13,800)
1997				5%	292,950	\$150	\$0	\$0	\$0	\$26,200	(\$26,200)
1998				5%	307,598	\$150	\$0	\$0	\$0	\$17,866	(\$17,866)
1999	1			5%	322,977	\$150	\$0	\$0	\$0	\$5,166	(\$1,941)
2000		5%	10%	5%	339,126	\$150	\$0	\$0	\$3,225	\$5,166	\$1,775
	2			5%	356,083	\$150	\$0	\$0	\$6,941	\$5,166	\$1,775
2001		3%	7%	3%	429,970	\$143	\$8	\$3,225	\$5,166	\$5,166	\$7,298
2002				3%	451,468	\$143	\$8	\$3,386	\$5,166	\$5,166	\$8,057
2003				3%	474,042	\$143	\$8	\$3,555	\$5,166	\$5,166	\$8,863
2004	3			3%	521,446	\$138	\$12	\$6,140	\$12,464	\$5,166	\$11,780
2005	4	1%	5%	1%	537,089	\$138	\$12	\$6,324	\$16,946	\$5,166	\$13,499
2006				3%	553,202	\$138	\$12	\$6,514	\$18,665	\$5,166	\$15,266
2007				3%	569,798	\$138	\$12	\$6,709	\$20,432	\$5,166	\$15,676
2008	5			3%	586,892	\$138	\$12	\$6,911	\$22,836	\$5,166	\$17,670
2009		1%		1%	604,499	\$138	\$12	\$7,118	\$24,885	\$5,166	\$19,719
2010	6			1%	640,768	\$137	\$13	\$8,431	\$28,892	\$5,166	\$23,726
2011				1%	647,176	\$137	\$13	\$8,515	\$29,473	\$5,166	\$24,307
		1%	5%	1%	653,648	\$137	\$13	\$8,600	\$30,000	\$5,166	\$24,834
				1%	692,867	\$135	\$15	\$10,064	\$30,000	\$5,166	\$24,834
				1%	699,795	\$135	\$15	\$10,165	\$30,000	\$5,166	\$24,834
				1%	706,793	\$135	\$15	\$10,267	\$30,000	\$5,166	\$24,834
				1%	713,861	\$135	\$15	\$10,369	\$30,000	\$5,166	\$24,834
				1%	721,000	\$135	\$15	\$10,473	\$30,000	\$5,166	\$24,834
				1%	728,210	\$135	\$15	\$10,578	\$30,000	\$5,166	\$24,834
		1%	5%	1%	771,903	\$134	\$16	\$12,258	\$30,000	\$5,166	\$24,834
				1%	779,622	\$134	\$16	\$12,381	\$30,000	\$5,166	\$24,834
				1%	787,418	\$134	\$16	\$12,505	\$30,000	\$5,166	\$24,834
		1%	5%	1%	834,663	\$133	\$17	\$14,374	\$30,000	\$5,166	\$24,834
				1%	843,009	\$133	\$17	\$14,518	\$30,000	\$5,166	\$24,834
				1%	851,440	\$133	\$17	\$14,663	\$30,000	\$5,166	\$24,834
				1%	859,954	\$133	\$17	\$14,810	\$30,000	\$5,166	\$24,834
Net Present Value										\$40,038	
Internal Rate of Return										12%	

Table 2-2c. Revised SAIC Study assumptions with waste processing rate equal to \$200/ft³.

FY	New Technology Deployed	Cost Reduction (percent)	Added Capacity (percent)	Industry Growth (percent)	Industry Capacity (cu. ft/6 mo.)	Avg. Cost (per cu. ft.)	Savings (per cu. ft.)	Total Savings (\$M)	Total Annual Savings (\$M)	Annual Costs (\$M)	Annual Cash Flow (\$M)
1996					279,000	\$200	\$0	\$0	\$0	\$13,800	(\$13,800)
				5%	292,950	\$200	\$0	\$0	\$0		
1997				5%	307,598	\$200	\$0	\$0	\$0	\$26,200	(\$26,200)
				5%	322,977	\$200	\$0	\$0	\$0		
1998				5%	339,126	\$200	\$0	\$0	\$0	\$17,866	(\$17,866)
				5%	356,083	\$200	\$0	\$0	\$0		
1999	1			5%	373,887	\$200	\$0	\$0	\$4,300	\$5,166	(\$866)
		5%	10%	5%	429,970	\$190	\$10	\$4,300			
2000				5%	451,468	\$190	\$10	\$4,515	\$9,255	\$5,166	\$4,089
	2			5%	474,042	\$190	\$10	\$4,740			
2001		3%	7%	3%	521,446	\$184	\$16	\$8,187	\$16,619	\$5,166	\$11,453
				3%	537,089	\$184	\$16	\$8,432			
2002				3%	553,202	\$184	\$16	\$8,685	\$17,631	\$5,166	\$12,465
				3%	569,798	\$184	\$16	\$8,946			
2003				3%	586,892	\$184	\$16	\$9,214	\$18,705	\$5,166	\$13,539
	3			3%	604,499	\$184	\$16	\$9,491			
2004		1%	5%	1%	640,768	\$182	\$18	\$11,241	\$22,594	\$5,166	\$17,428
				1%	647,176	\$182	\$18	\$11,353			
2005	4			1%	653,648	\$182	\$18	\$11,467	\$24,886	\$5,166	\$19,720
		1%	5%	1%	692,867	\$181	\$19	\$13,419			
2006				1%	699,795	\$181	\$19	\$13,553	\$27,242	\$5,166	\$22,076
				1%	706,793	\$181	\$19	\$13,689			
2007				1%	713,861	\$181	\$19	\$13,826	\$27,790	\$5,166	\$22,624
				1%	721,000	\$181	\$19	\$13,964			
2008	5			1%	728,210	\$181	\$19	\$14,104	\$30,448	\$5,166	\$25,282
		1%	5%	1%	771,903	\$179	\$21	\$16,344			
2009				1%	779,622	\$179	\$21	\$16,508	\$33,180	\$5,166	\$28,014
	6			1%	787,418	\$179	\$21	\$16,673			
2010		1%	5%	1%	834,663	\$177	\$23	\$19,166	\$38,523	\$5,166	\$33,357
				1%	843,009	\$177	\$23	\$19,357			
2011				1%	851,440	\$177	\$23	\$19,551	\$39,297	\$5,166	\$34,131
				1%	859,954	\$177	\$23	\$19,746			
Net Present Value										\$84,804	
Internal Rate of Return										17%	

Table 2-2d. Revised SAIC Study assumptions with waste processing rate equal to \$250/ft³.

FY	New Technology Deployed	Cost Reduction (percent)	Added Capacity (percent)	Industry Growth (percent)	Industry Capacity (cu. ft/6 mo.)	Avg. Cost (per cu. ft.)	Savings (per cu. ft.)	Total Savings (\$k)	Total Annual Savings (\$k)	Annual Costs (\$k)	Annual Cash Flow (\$k)
1996					279,000	\$250	\$0	\$0	\$0	\$13,800	(\$13,800)
				5%	292,950	\$250	\$0	\$0	\$0		
1997				5%	307,598	\$250	\$0	\$0	\$0	\$26,200	(\$26,200)
				5%	322,977	\$250	\$0	\$0			
1998				5%	339,126	\$250	\$0	\$0	\$0	\$17,866	(\$17,866)
				5%	356,083	\$250	\$0	\$0			
1999	1			5%	373,887	\$250	\$0	\$0	\$5,375	\$5,166	\$209
		5%	10%	5%	429,970	\$238	\$13	\$5,375			
2000				5%	451,468	\$238	\$13	\$5,643	\$11,569	\$5,166	\$6,403
	2			5%	474,042	\$238	\$13	\$5,926			
2001		3%	7%	3%	521,446	\$230	\$20	\$10,233	\$20,774	\$5,166	\$15,608
				3%	537,089	\$230	\$20	\$10,540			
2002				3%	553,202	\$230	\$20	\$10,857	\$22,039	\$5,166	\$16,873
				3%	569,798	\$230	\$20	\$11,182			
2003				3%	586,892	\$230	\$20	\$11,518	\$23,381	\$5,166	\$18,215
	3			3%	604,499	\$230	\$20	\$11,863			
2004		1%	5%	1%	640,768	\$228	\$22	\$14,051	\$28,243	\$5,166	\$23,077
				1%	647,176	\$228	\$22	\$14,192			
2005	4			1%	653,648	\$228	\$22	\$14,334	\$31,108	\$5,166	\$25,942
		1%	5%	1%	692,867	\$226	\$24	\$16,774			
2006				1%	699,795	\$226	\$24	\$16,942	\$34,053	\$5,166	\$28,887
				1%	706,793	\$226	\$24	\$17,111			
2007				1%	713,861	\$226	\$24	\$17,282	\$34,737	\$5,166	\$29,571
				1%	721,000	\$226	\$24	\$17,455			
2008	5			1%	728,210	\$226	\$24	\$17,630	\$38,060	\$5,166	\$32,894
		1%	5%	1%	771,903	\$224	\$26	\$20,430			
2009				1%	779,622	\$224	\$26	\$20,635	\$41,475	\$5,166	\$36,309
	6			1%	787,418	\$224	\$26	\$20,841			
2010		1%	5%	1%	834,663	\$221	\$29	\$23,957	\$48,154	\$5,166	\$42,988
				1%	843,009	\$221	\$29	\$24,197			
2011				1%	851,440	\$221	\$29	\$24,439	\$49,122	\$5,166	\$43,956
				1%	859,954	\$221	\$29	\$24,683			
Net Present Value										\$129,570	
Internal Rate of Return										21%	

Table 2-2e. Revised SAIC Study assumptions with waste processing rate equal to \$300/ft³.

FY	New Technology Deployed	Cost Reduction (percent)	Added Capacity (percent)	Industry Growth (percent)	Industry Capacity (cu. ft/6 mo.)	Avg. Cost (per cu. ft.)	Savings (per cu. ft.)	Total Savings (\$M)	Total Annual Savings (\$M)	Annual Costs (\$M)	Annual Cash Flow (\$M)
1996					279,000	\$300	\$0	\$0	\$0	\$13,800	(\$13,800)
				5%	292,950	\$300	\$0	\$0			
1997				5%	307,598	\$300	\$0	\$0	\$0	\$26,200	(\$26,200)
				5%	322,977	\$300	\$0	\$0			
1998				5%	339,126	\$300	\$0	\$0	\$0	\$17,866	(\$17,866)
				5%	356,083	\$300	\$0	\$0			
1999	1			5%	373,887	\$300	\$0	\$0	\$6,450	\$5,166	\$1,284
		5%	10%	5%	429,970	\$285	\$15	\$6,450			
2000				5%	451,468	\$285	\$15	\$6,772	\$13,883	\$5,166	\$8,717
	2			5%	474,042	\$285	\$15	\$7,111			
2001		3%	7%	3%	521,446	\$276	\$24	\$12,280	\$24,928	\$5,166	\$19,762
				3%	537,089	\$276	\$24	\$12,648			
2002				3%	553,202	\$276	\$24	\$13,028	\$26,447	\$5,166	\$21,281
				3%	569,798	\$276	\$24	\$13,419			
2003				3%	586,892	\$276	\$24	\$13,821	\$28,057	\$5,166	\$22,891
	3			3%	604,499	\$276	\$24	\$14,236			
2004		1%	5%	1%	640,768	\$274	\$26	\$16,862	\$33,892	\$5,166	\$28,726
				1%	647,176	\$274	\$26	\$17,030			
2005	4			1%	653,648	\$274	\$26	\$17,200	\$37,329	\$5,166	\$32,163
		1%	5%	1%	692,867	\$271	\$29	\$20,129			
2006				1%	699,795	\$271	\$29	\$20,330	\$40,863	\$5,166	\$35,697
				1%	706,793	\$271	\$29	\$20,533			
2007				1%	713,861	\$271	\$29	\$20,739	\$41,685	\$5,166	\$36,519
				1%	721,000	\$271	\$29	\$20,946			
2008	5			1%	728,210	\$271	\$29	\$21,155	\$45,672	\$5,166	\$40,506
		1%	5%	1%	771,903	\$268	\$32	\$24,516			
2009				1%	779,622	\$268	\$32	\$24,761	\$49,770	\$5,166	\$44,604
	6			1%	787,418	\$268	\$32	\$25,009			
2010		1%	5%	1%	834,663	\$266	\$34	\$28,748	\$57,784	\$5,166	\$52,618
				1%	843,009	\$266	\$34	\$29,036			
2011				1%	851,440	\$266	\$34	\$29,326	\$58,946	\$5,166	\$53,780
				1%	859,954	\$266	\$34	\$29,620			
Net Present Value										\$174,335	
Internal Rate of Return										25%	

Table 2-3a. Revised SAIC Study Assumptions: Initial Waste Processing Rate on "Interim End-State" Analysis by DOE/HQ.

FY	New Technology Deployed	Cost Reduction (percent)	Added Capacity (percent)	Industry Growth (percent)	Industry Capacity (cu m/6 mo.)	Industry Capacity (cu. ft/6 mo.)	Avg. Cost (per cu. ft.)	Savings (per cu. ft.)	Total Savings (\$k)	Total Annual Savings (\$k)	Annual Costs (\$k)	Annual Cash Flow (\$k)
1996					2,500	88,275	\$200	\$0	\$0	\$0	\$13,800	(\$13,800)
					2,500	88,275	\$200	\$0	\$0	\$0		
1997					3,613	127,575	\$200	\$0	\$0	\$0	\$26,200	(\$26,200)
					3,613	127,575	\$200	\$0	\$0	\$0		
1998					6,663	235,271	\$200	\$0	\$0	\$0	\$17,866	(\$17,866)
					6,663	235,271	\$200	\$0	\$0	\$0		
1999	1			5%		247,034	\$200	\$0	\$0	\$2,841	\$5,166	(\$2,325)
		5%	10%	5%		284,089	\$190	\$10	\$2,841			
2000				5%		298,294	\$190	\$10	\$2,983	\$6,115	\$5,166	\$949
	2			5%		313,208	\$190	\$10	\$3,132			
2001		3%	7%	3%		344,529	\$184	\$16	\$5,409	\$10,980	\$5,166	\$5,814
				3%		354,865	\$184	\$16	\$5,571			
2002				3%		365,511	\$184	\$16	\$5,739	\$11,649	\$5,166	\$6,483
				3%		376,476	\$184	\$16	\$5,911			
2003				3%		387,771	\$184	\$16	\$6,088	\$12,359	\$5,166	\$7,193
	3			3%		399,404	\$184	\$16	\$6,271			
2004		1%	5%	1%		423,368	\$182	\$18	\$7,427	\$14,929	\$5,166	\$9,763
				1%		427,602	\$182	\$18	\$7,501			
2005	4			1%		431,878	\$182	\$18	\$7,576	\$16,443	\$5,166	\$11,277
		1%	5%	1%		457,790	\$181	\$19	\$8,866			
2006				1%		462,368	\$181	\$19	\$8,955	\$17,999	\$5,166	\$12,833
				1%		466,992	\$181	\$19	\$9,044			
2007				1%		471,662	\$181	\$19	\$9,135	\$18,361	\$5,166	\$13,195
				1%		476,378	\$181	\$19	\$9,226			
2008	5			1%		481,142	\$181	\$19	\$9,319	\$20,117	\$5,166	\$14,951
		1%	5%	1%		510,011	\$179	\$21	\$10,799			
2009				1%		515,111	\$179	\$21	\$10,907	\$21,923	\$5,166	\$16,757
	6			1%		520,262	\$179	\$21	\$11,016			
2010		1%	5%	1%		551,478	\$177	\$23	\$12,663	\$25,453	\$5,166	\$20,287
				1%		556,992	\$177	\$23	\$12,790			
2011				1%		562,562	\$177	\$23	\$12,918	\$25,964	\$5,166	\$20,798
				1%		568,188	\$177	\$23	\$13,047			
Net Present Value											\$24,051	
Internal Rate of Return											9%	

Table 2-3b. Revised SAIC Study Assumptions: Initial Waste Processing Rate Set To 10% of "Interim End-State" Analysis by DOE/HQ.

FY	New Tech.	Cost Reduction (percent)	Added Capacity (percent)	Industry Growth (percent)	Industry Capacity (M/6mo.)	Industry Capacity (cu. ft/6 mo.)	Avg. Cost (per cu. ft.)	Savings (per cu. ft.)	Total Savings (\$k)	Total Annual Savings (\$k)	Annual Costs (\$k)	Annual Cash Flow (\$k)
1996					250	8,828	\$400	\$0	\$0	\$0	\$13,800	(\$13,800)
					250	8,828	\$400	\$0	\$0	\$0		
1997					361	12,758	\$400	\$0	\$0	\$0	\$26,200	(\$26,200)
					361	12,758	\$400	\$0	\$0	\$0		
1998					666	23,527	\$400	\$0	\$0	\$0	\$17,866	(\$17,866)
					666	23,527	\$400	\$0	\$0	\$0		
1999	1			5%		24,703	\$400	\$0	\$0	\$568	\$5,166	(\$4,598)
		5%	10%	5%		28,409	\$380	\$20	\$568			
2000				5%		29,829	\$380	\$20	\$597	\$1,223	\$5,166	(\$3,943)
	2			5%		31,321	\$380	\$20	\$626			
2001		3%	7%	3%		34,453	\$369	\$31	\$1,082	\$2,196	\$5,166	(\$2,970)
				3%		35,487	\$369	\$31	\$1,114			
2002				3%		36,551	\$369	\$31	\$1,148	\$2,330	\$5,166	(\$2,836)
				3%		37,648	\$369	\$31	\$1,182			
2003				3%		38,777	\$369	\$31	\$1,218	\$2,472	\$5,166	(\$2,694)
	3			3%		39,940	\$369	\$31	\$1,254			
2004		1%	5%	1%		42,337	\$365	\$35	\$1,485	\$2,986	\$5,166	(\$2,180)
				1%		42,760	\$365	\$35	\$1,500			
2005	4			1%		43,188	\$365	\$35	\$1,515	\$3,289	\$5,166	(\$1,877)
		1%	5%	1%		45,779	\$361	\$39	\$1,773			
2006				1%		46,237	\$361	\$39	\$1,791	\$3,600	\$5,166	(\$1,566)
				1%		46,699	\$361	\$39	\$1,809			
2007				1%		47,166	\$361	\$39	\$1,827	\$3,672	\$5,166	(\$1,494)
				1%		47,638	\$361	\$39	\$1,845			
2008	5			1%		48,114	\$361	\$39	\$1,864	\$4,023	\$5,166	(\$1,143)
		1%	5%	1%		51,001	\$358	\$42	\$2,160			
2009				1%		51,511	\$358	\$42	\$2,181	\$4,385	\$5,166	(\$781)
	6			1%		52,026	\$358	\$42	\$2,203			
2010		1%	5%	1%		55,148	\$354	\$46	\$2,533	\$5,091	\$5,166	(\$75)
				1%		55,699	\$354	\$46	\$2,558			
2011				1%		56,256	\$354	\$46	\$2,584	\$5,193	\$5,166	\$27
				1%		56,819	\$354	\$46	\$2,609			
Net Present Value											(\$70,598)	
Internal Rate of Return											#DIV/0!	

3.0 Case-Specific Cost Benefit Studies

The "global" SAIC analysis of the MWMF cost benefit shows very high leverage of a national testbed for pilot-scale demonstrations (see Section 2.0 and Appendix A). In addition to this analysis, we have identified a number of more limited and specific case scenarios that provide an alternative approach to estimating the MWMF return-on-investment (ROI). These are based on varying assumptions as to how and where the technologies that are successfully demonstrated in the MWMF are deployed, as well as how many. We analyze the following specific cases:

- Case 1** Estimate the cost benefit of commercial deployment of an Unspecified Non-Incineration Technology (UNIT) using the MWMF for coordinated, integrated pilot-scale demonstrations prior to deployment vs. commercial deployment from the preconceptual stage (laboratory- and bench-scale test information only).
- Case 1a.** Consider deployment of non-incinerator systems in the four non-incineration states (NISs)—CA, NM, CO, and OH. In this analysis, the cost benefit is realized as a result of the reduction in contingency for plant construction.
- Case 1b.** Similar to Case 1a, with the deployment of non-incinerator systems expanded to the DOE complex under the assumption that incineration is no longer viable for mixed waste treatment.
- Case 1c.** Similar to Case 1a, with the cost benefit linked to start-up and operations improvement.
- Case 2** Estimate the cost benefit of deploying UNITs using the MWMF for coordinated, integrated pilot-scale demonstrations prior to deployment vs. independent demonstrations at the selected site.
- Case 2a.** Consider deployment of non-incinerator systems in the NISs.
- Case 2b.** Consider deployment throughout the DOE complex.
- Case 3** Estimate the cost benefit of deploying UNITs in the NISs vs. shipping all waste to incineration sites.

In reality, many of these cost benefits are cumulative, in that the general benefits detailed in Section 2 will be combined with the benefits for the various cases presented here. For instance, the cost benefit of increasing competition and thus reducing cost for treatment does not preclude the cost benefit of consolidating treatment demonstrations into a single integrated facility. Similarly, the cost savings resulting from the reduction of contingency for plant construction occur even if we also improve operational efficiencies. As such, the benefits described do not convey the full benefit potentially realized.

For the following analyses, it is assumed that up to three integrated technologies can be demonstrated in the MWMF concurrently (current design baseline), and that demonstrations are typically 18 months (based on analysis for initial systems for the MWMF). Further, due to the imminent needs of (and the *Site Treatment Plan* agreements with) the respective states, we anticipate that the "early phase" demonstrations will be conducted over the first 8 to 12 years of MWMF operations. While the facility is capable of significantly more treatment demonstrations over its life of 20+ years, this conservative assumption should provide a lower estimate for the ROI. The effective costs in the MWMF would be significantly lower in the out years, and the use of the facility to address other important waste treatment needs could be expanded.

The cost bases for the ROI calculations use data from a number of sources. Costs for large facilities, life-cycle costs, and costs for independent demonstrations are adapted from EM-50 Integrated Thermal Treatment System (ITTS) studies for incineration and other thermal technologies (Refs. 1, 2). Plant costs for small to mid-size nonincineration systems are extrapolated from MWMF cost estimates for an integrated facility (Ref. 3). Mixed low-level waste inventories were taken from the Mixed Waste Inventory Report reported in *Integrated Data Base Report—1994: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections and Characteristics* (Ref. 4). Table 3-1 shows an extract from this reference for the NISs.

Costs for waste preparation, transportation, and storage are based on LLNL data from 1995 (Ref. 5). Costs for external processing of mixed waste have been obtained from commercial facilities currently approved to receive specific mixed waste streams.

Table 3-1. Cumulative volume inventory of RCRA and state-regulated MLLW at sites in "non-incineration states."

Site	Category	Current Inventory Volume (m ³) (Ref 4, Table 8.7)	Number of Facilities (note 1)	Facility Size (note 2)
ETEC	Organic liquids	0.15		
	Sub total	0.15		
FEMP	Aqueous liquids/slurries	869.80	1	medium
	Heterogeneous debris	26.60		
	Lab packs	0.40		
	Organic debris	21.20		
	Organic homogeneous	78.20		
	Solids			
	Organic liquids	374.80	1	small
	Sub total	1371.00		
LANL	Aqueous liquids/slurries	3.34		
	Heterogeneous debris	6.32		
	Organic debris	42.14		
	Organic liquids	55.42		
	Sub total	107.22	1	small
LBL	Aqueous liquids/slurries	2.16		
	Heterogeneous debris	0.11		
	Lab packs	0.15		
	Organic liquids	3.30		
	Sub total	5.72		
LLNL	Heterogeneous debris	62.40		
	Lab packs	6.30		
	Organic homogeneous	1.20		
	Solids			
	Organic liquids	92.80		
	Sub total	162.70	1	small
MOUND	Lab packs	43.47		
	Organic liquids	28.50		
	Sub total	71.97		
PORTS	Aqueous liquids/slurries	113.33		
	Heterogeneous debris	842.33	1	medium
	Lab packs	29.20		
	Organic debris	280.44		
	Organic homogeneous	273.60	1	medium
	Solids			
	Organic liquids	250.79	1	medium
	Sub total	1789.69		

Note 1: It is assumed that a primary process will be deployed to every site with an aggregate inventory of 100 or more cu m. Multiple process trains will be deployed if individual or like streams exceed this value. This assumption is based on a five-year period to complete backlog and maintain pace with annual waste generation

Note 2: Facility size is classified as small (1–100 cu m/yr capacity), medium (100–500 cu m/yr capacity), or large (capacity greater than 500 cu m/yr).

Table 3-1. Cumulative volume inventory of RCRA and state-regulated MLLW at sites in "non-incineration states" (cont.).

Site	Category	Current Inventory Volume (m ³) (Ref 4, Table 8.7)	Number of Facilities (note 1)	Facility size (note 2)
RFP	Aqueous liquids/slurries	533.26	1	medium
	Heterogeneous Debris	6.66		
	Lab packs	47.38		
	Organic Debris	1241.53	1	medium
	Organic liquids	130.80	1	small
	Sub total	1959.63		
RMI	Aqueous liquids/slurries	2.43		
	Organic Debris	3.53		
	Organic liquids	7.00		
	Sub total	12.96		
SNL/CA	Lab packs	0.40		
	Sub total	0.40		
SNL/NM	Aqueous liquids/slurries	0.02		
	Heterogeneous Debris	4.37		
	Organic Debris	28.60		
	Organic liquids	2.91		
	Sub total	35.90		
Others	Aqueous liquids/slurries	43.98	1	medium
	Heterogeneous Debris	647.03		
	Lab packs	4.48		
	Organic Debris	320.44		
	Organic Homogeneous Solids	2.27		
	Organic liquids	60.68		
	Sub total	1078.88		
Sub Totals by waste stream	Aqueous liquids/slurries	1568.32		
	Heterogeneous Debris	1595.82		
	Lab packs	131.78		
	Organic Debris	1937.88		
	Organic Homogeneous Solids	355.27		
	Organic liquids	1007.15		
	Sub total			
Grand total		6596.22	11	processes

Note 1: It is assumed that a primary process will be deployed to every site with an aggregate inventory of 100 or more cu m.

Multiple process trains will be deployed if individual or like streams exceed this value. This assumption is based on a five-year period to complete backlog and maintain pace with annual waste generation

Note 2: Facility size is classified as small (1–100 cu m/yr capacity), medium (100–500 cu m/yr capacity), or large (capacity greater than 500 cu m/yr).

3.1 Case 1: Commercial Deployment of Non-Incineration Technologies

Estimate the cost benefit of commercial deployment of UNITs using the MWMF for coordinated, integrated pilot-scale demonstrations prior to deployment vs. commercial deployment from the preconceptual stage (laboratory- and bench-scale test information only).

This case is divided into three alternative analyses. Case 1a is based on the expected commercial plant cost with and without pilot-scale demonstrations. The pilot-scale demonstrations relate to the relative stage of technology development when the contract is bid, and as such, the contingency that will be built into the facility costs. In particular, this case focuses on deployment in the four non-incineration states—CA, NM, CO, and OH. Case 1b is the same as 1a with the deployment option expanded to the DOE complex under the assumption that alternatives to incineration will be required complexwide. Case 1c approaches commercial deployment in different ways. We assess the benefit relative to the efficiencies gained during commercial plant start-up, activation, and operations using information gained by pilot-scale demonstrations in the MWMF vs. direct scale-up from existing knowledge. This case only addresses the NISs.

Case 1a: Non-Incineration States Only—CA, NM, CO, and OH

A significant cost benefit derived from the MWMF is in the reduction of cost for a treatment facility after significant pilot-scale demonstration and engineering development has been completed. In a study conducted for the DOE (Ref. 6), Rand Corp. shows that the cost of a facility can be directly related to the stage of development of the systems to be deployed. As shown in Figure 3.1 (taken from Ref. 6), the estimated cost decreases dramatically from the preconceptual design phase, identified as "0" on the abscissa, through conceptual design, "2," and through preliminary and final designs, "2" and "3" respectively. The cost is manifested in the increased contingency required if the stage of development is low. For instance, a \$50M plant design per preconceptual analysis will be costed at \$100M (100% contingency) to reflect expected actual cost based on historical data. For a design conducted after conceptual design and into preliminary design, the contingency is reduced significantly—to about 40%. A \$50M estimate will be increased to \$70M to include the contingency expected for project completion. This difference of \$30M is a realized cost to the DOE for commercial deployment of treatment facilities.

Using this approach, the cost benefit for completing engineering scale-up and development in the MWMF (or elsewhere) prior to commercialization is evaluated relative to commercialization based on the current state of development—laboratory- and bench-scale studies. To complete this assessment, we determine the number of commercial waste treatment facilities to be constructed, the expected cost, and the stage of development prior to and after demonstration in the MWMF.

Figure 3.1.

Estimated cost to actual cost for facility deployment as a function of stage of development. "0" refers to preconceptual design (e.g., during R&D phase of process development), whereas estimate class "2" to "3" refers to the equivalent of preliminary design. (Based on Ref. 6).

The number of facilities to be built to address the waste treatment needs in the NIS is estimated based on the waste inventories at the specific sites. The first three columns of Table 3-1 (extracted from Ref. 4) identify the waste streams at the major facilities in the NIS that can be treated effectively using alternatives to incineration—these are also the waste streams that have been targeted for demonstration in the MWMF. The fourth column of Table 3-1 shows an estimate of the number of treatment processes and facilities anticipated to effectively handle this volume of waste. The number of facilities is determined by considering the total volume of waste at each site (sites with greater than 100 m³ of current inventory of specified waste); the site location (required to have at least one facility in each of the four NIS), and the distribution of waste. Based on this assessment, it appears that facilities will be required at a minimum of five sites. Further, to meet the diversity of waste treatment needs, three or four different types of processes are likely to be deployed (aqueous liquids/slurries, organic liquids, organic homogeneous solids, heterogeneous and organic debris), and about 11 processes in all.

The size of the treatment facility, the number of primary treatment systems, and the cost of construction and activation of these facilities are subsequently estimated. Table 3-2 describes the facility size groupings used in this study and the estimated cost of each facility. The facility cost range is a function of the number and size of the primary treatment systems deployed, the minimum number being the base cost for a treatment facility infrastructure without specific treatment processes. The number and size of UNITs will determine the cost delta over the minimum treatment facility cost. The sizes of the process systems, which govern the facility size, were estimated based on the criterion that the backlog of waste can be treated in a five-year period while maintaining current with the newly generated waste. Three classes of facilities are defined: small, medium, and large. In all cases for the NISs, facility sizes were either small or medium. The larger systems are only being anticipated for large centralized facilities.

The costs for deploying specific technologies at treatment facilities described above are based on the data in Table 3-3. Other infrastructure elements (such as shipping and receiving areas, feed preparation, water treatment, final forms, decontamination, instrumentation and controls, and offices) are contained in the base number for each facility. The size of the facility is determined by the size of the largest UNIT to be deployed at that facility.

Table 3-4a brings together the various plant cost elements. From the previously described model, the total cost for a treatment facility can be estimated with and without the use of the MWMF to address conceptual and preliminary design issues. From this evaluation, the cost for small and medium treatment facilities ranges from \$140M to \$440M without the MWMF and from \$98M to \$308M with the

Table 3-2. Facility size description and cost estimate (uncontingent).

Facility Size	Description	Cost/Basis
Small	Capacity to treat 1 to 100 m ³ of MLLW/year, roughly equivalent to the size of the pilot-scale equipment deployed in the MWMF.	\$50M base cost \$70–100M plant range Basis: MWMF model, process and facility costs are similar to MWMF, decreased to account for well-defined technologies. Cost range to account for the number of process technologies to be deployed at plant, and the complexity of systems.
Medium	Capacity to treat 100 to 500 m ³ of MLLW/year, roughly 5 to 10 times the capacity of the MWMF pilot-scale equipment.	\$100M base cost \$140–180M plant range Basis: MWMF model, process and facility costs are scaled from MWMF approximately 2x. Process equipment and facility increase, but engineering design and project overheads maintained. Cost range to account for the number of process technologies to be deployed at plant, and the complexity of systems.
Large	Capacity to treat >500 m ³ of MLLW/year, greater than 10 times the capacity of the MWMF pilot-scale equipment.	\$180M base cost \$280–500M plant range Basis: ITTS study for specific technology deployment. Cost range to account for the number of process technologies to be deployed at plant, and the complexity of systems.

Table 3-3. Unspecified non-incineration technology (UNIT) size description and cost estimate.

UNIT Size	Description	Cost/Basis
Small	Capacity to treat 1–100 m ³ of MLLW/year, roughly equivalent to the size of the pilot-scale equipment deployed in the MWMF.	\$20M UNIT average \$10–30M UNIT range Basis: MWMF model, process equipment costs will range from MWMF to 2× MWMF systems.
Medium	Capacity to treat 100–500 m ³ of MLLW/year, roughly five to ten times the capacity of the MWMF pilot-scale equipment.	\$40M UNIT average \$30–50M UNIT range Basis: MWMF model, process costs are scaled up from the MWMF to account for significantly greater throughput. Cost increase generally associated with equipment.
Large	Capacity to treat >500 m ³ of MLLW/year, greater than ten times the capacity of the MWMF pilot-scale equipment.	\$100M UNIT average \$50–150M UNIT range Basis: ITTS study for specific technology deployment (excluding contingency)

Table 3-4a. Estimate of commercial treatment plant costs with and without the use of MWMF (NIS).

Site	Facility Size (note 1)	UNIT Designation Number and size of UNITs (note 2)	Conventional Facility Cost \$M	UNIT Cost \$M	Uncontingent Treatment Plant Cost \$M	Commercialization costs from pre-conceptual design \$M	Commercialization costs from preliminary design \$M	MWMF Demonstration Costs (Note 3) \$M	Sum of Commercialization costs with MWMF Demonstrations
						Contingency = 100%	Contingency = 40%		
MWMF Project and Infrastructure								\$40.6	
MWMF Operations								\$21.5	
Site-1	medium	UNIT-2 a 1 medium UNIT-3 a 1 small	\$100.0	\$40.0 \$20.0	\$160.0	\$320.0	\$224.0	\$14.6 \$14.6	\$253.2
Site-2	small	UNIT-2 b 1 small	\$50.0	\$20.0	\$70.0	\$140.0	\$98.0	\$7.2	\$105.2
Site-3	small	MSO a 1 small	\$50.0	\$20.0	\$70.0	\$140.0	\$98.0	\$14.6	\$112.6
Site-4	medium	UNIT-4 a 1 medium UNIT-5 a 1 medium UNIT-6 a 1 medium	\$100.0	\$40.0 \$40.0 \$40.0	\$220.0	\$440.0	\$308.0	\$14.6 \$14.6 \$14.6	\$351.8
Site-5	medium	UNIT-4 b 1 medium UNIT-7 a 1 medium UNIT-6 b 1 small	\$100.0	\$40.0 \$40.0 \$20.0	\$200.0	\$400.0	\$280.0	\$7.2 \$14.6 \$7.2	\$309.0
Site-6	medium	UNIT-8 a 1 medium	\$100.0	\$40.0	\$140.0	\$280.0	\$196.0	\$14.6	\$210.6
Total		# UNITs 11				\$1,720.0	\$1,204.0	\$200.5	\$1,404.5

Table 3-4b. Estimate of net-present-value and rate-of-return for commercial treatment plant deployment with and without use of MWMF (NIS).

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
System Demonstrated Facility Site Deployed			1, 2a	2b	3a, 4a	4b	5a, 6a	6b	7a, 8a
			3	2	1		4		5, 6
MWMF Capital Costs	(\$25.6)								
DWTF Facility Costs	(\$15.0)								
MWMF Operations Cost		(\$2.5)	(\$2.5)	(\$2.5)	(\$2.5)	(\$2.5)	(\$3.0)	(\$3.0)	(\$3.0)
MWMF Demonstrations Cost		(\$14.6)	(\$19.4)	(\$17.0)	(\$19.4)	(\$17.0)	(\$19.4)	(\$17.0)	(\$14.6)
Facility Commercialization with MWMF			(\$98.0)	(\$98.0)	(\$224.0)		(\$308.0)		(\$476.0)
Facility Commercialization without MWMF			\$140.0	\$140.0	\$320.0		\$440.0		\$680.0
Total Annual (Cost) Savings	(\$40.6)	(\$17.1)	\$20.1	\$22.5	\$74.1	(\$19.5)	\$109.6	(\$20.0)	\$186.4

Discount Rate Net Present Value (\$M)	
3%	\$247
4%	\$227
5%	\$210
6%	\$193
7%	\$179

Internal Rate of Return = 44%

MWMF (including costs for MWMF project and demonstrations). The net present value (NPV) is calculated as shown in Table 3-4b. For a discount rate of 5%, the NPV is \$210M. Similarly, the internal rate of return (annual rate) is also calculated to be 44%.

Case 1b: DOE Complexwide

As an expansion of Case 1a, the deployment of non-incineration technologies is expanded to the DOE complex under the assumption that alternatives to incineration will be required complexwide (Case 1b). The number of facilities and size of treatment facilities to be built must account for the total volume of incinerable waste throughout the DOE complex. Table 3-5 compares the waste inventories in the NISs vs. the same waste streams throughout the DOE complex. Unlike the Case 1a evaluation, in which specific sites were selected for treatment facilities based on their inventory of waste, the waste inventory for the complex is divided into categories such that the baseline assumption can be achieved; that is, waste inventory backlog can be eliminated in five years while maintaining current or newly generated waste. Based on this assumption, either many small to medium facilities must be constructed, or a smaller number of large facilities. For this case, it is conservatively assumed that facilities will be built at 10 sites and that 20 primary waste treatment processes will be deployed (of which there will be 11 different technologies). Although this is somewhat less than the estimated capacity requirements, the large facilities may include systems capable of significantly more than 500 m³/year.

Using the approach described in Case 1a, the data from Table 3-4 can be recalculated based on a broader deployment required for the DOE complex. Table 3-6 describes a scenario in which eight large treatment facilities and two medium facilities are built. At each facility two primary processes are deployed: a large and a medium or two medium systems. In addition, it is assumed that the same process will be deployed at a number of locations. For the scenario calculated, it is assumed that one process is deployed in four plants, one is deployed in three plants and four others are deployed at two sites. The remaining systems are unique to the specific sites and waste streams. This distribution was chosen to reflect a wide range of technologies demonstrated in which some are robust and can be deployed in a variety of situations while others are more specific to the specific waste streams. Based on this analysis, the NPV is almost \$1 billion (5% discount rate) by having a centralized, integrated demonstration facility for process evaluation. The annual rate of return is 78%.

A second factor, which is not well quantified in this type of ROI case study, is that integrated demonstrations at a meaningful scale will mitigate the potential of the design and construction of treatment facilities that are not capable of handling the intended waste streams, that require major modifications prior to full-scale operations, or that—due to the lack of public acceptance—cannot be operated after

Table 3-5a. Inventory comparison between NIS and DOE Complex.

	Category	Current NIS inventory Volume (m ³) (Ref. 4, Table 8.7)	Current DOE complex inventory Volume (m ³) (Ref. 4, Table 8.8)	Projected 5-year Cumulative Volume (m ³) (Ref. 4, Table 8.9)	Annual processing rate m ³ /yr (note 1)
Sub Totals by waste stream	Aqueous liquids/slurries	1568.32	5110.56	8401.97	2703
	Heterogeneous debris	1595.82	8417.58	3797.89	2443
	Lab packs	131.78	492.72	934.27	285
	Organic debris	1937.88	9287.65	4575.32	2773
	Organic Homogeneous solids	355.27	770.81	161.6	186
	Organic liquids	1007.15	2082.38	2100.98	837
Grand total		6596.22	26161.70	19972.03	9227

Ratio of DOE current waste volume to NIS vol. 4.0

Ratio of annual generation rate to current inventory
(based on DOE complex wide) 0.15

Note 1: Annual processing rate assumes backlog inventory is depleted in 5 years while keeping up with current annual waste generation, e.g.,

rate = (current inventory)/5 + 5-yr. projection)/5

Table 3-5b. Estimate of treatment facilities required to meet waste processing needs in "non-incineration states" and at DOE complexwide. (Note 2)

Category	Deployed treatment systems to meet NIS waste inventory requirements	Deployed treatment systems to meet DOE Complex waste inventory requirements	Deployed treatment systems to meet DOE Complex waste inventory requirements
	200 m ³ /yr process	200 m ³ /yr process	500 m ³ /yr process
Aqueous liquids/slurries	3	14	5
Heterogeneous debris	3	12	5
Lab packs	0	1	1
Organic debris	3	14	6
Organic Homogeneous solids	1	1	0
Organic liquids	2	4	2
	12	46	18

Note 2: To estimate the number of treatment facilities required, processes are assumed to operate 2000 h/yr. Small treatment systems will process waste at 20 kg/h, medium systems at 100 kg/h and large systems at 250 kg/h. Resulting annual rates are 40 m³/yr, 200 m³/yr and 500 m³/yr for small, medium and large facilities respectively.

Table 3-6a. Estimate of commercial treatment plant costs with and without the use of MWMF (DOE complex).

Site	Facility Size	UNIT Designation	Number and Size of UNITS	Conventional Facility Cost	UNIT Cost	Uncontingent Treatment Plant Cost	Commercialization costs from pre-conceptual design	Commercialization costs from preliminary design	MWMF Demonstration Costs	Sum of Commercialization costs with MWMF Demonstrations
				\$M	\$M	\$M	\$M	\$M	\$M	
MWMF Project and Infrastructure							Contingency = 100%	Contingency = 40%	\$40.6	
MWMF Operations									\$31.0	
Site-1	large	UNIT-2a	1 large	\$180.0	\$100.0	\$320.0	\$640.0	\$448.0	\$14.6	\$477.2
Site-2	large	UNIT-3a	1 medium	\$180.0	\$40.0	\$320.0	\$640.0	\$448.0	\$14.6	\$469.8
		UNIT-4a	1 large		\$100.0				\$7.2	
Site-3	large	UNIT-2b	1 medium	\$180.0	\$40.0	\$320.0	\$640.0	\$448.0	\$14.6	\$469.8
		UNIT-5a	1 large		\$100.0				\$7.2	
Site-4	large	UNIT-4b	1 medium	\$180.0	\$40.0	\$320.0	\$640.0	\$448.0	\$14.6	\$477.2
		UNIT-7a	1 large		\$100.0				\$14.6	
Site-5	large	UNIT-6a	1 medium	\$180.0	\$40.0	\$320.0	\$640.0	\$448.0	\$7.2	\$469.8
		UNIT-6b	1 large		\$100.0				\$14.6	
Site-6	large	UNIT-9a	1 medium	\$180.0	\$40.0	\$320.0	\$640.0	\$448.0	\$14.6	\$477.2
		UNIT-8a	1 large		\$100.0				\$14.6	
Site-7	large	UNIT-10a	1 medium	\$180.0	\$40.0	\$320.0	\$640.0	\$448.0	\$7.2	\$469.8
		UNIT-8b	1 large		\$100.0				\$14.6	
Site-8	large	UNIT-11a	1 medium	\$180.0	\$40.0	\$320.0	\$640.0	\$448.0	\$7.2	\$462.4
		UNIT-4c	1 large		\$100.0				\$7.2	
Site-9	medium	UNIT-5b	1 medium	\$100.0	\$40.0	\$180.0	\$360.0	\$252.0	\$14.6	\$273.8
		MSO,a	1 medium		\$40.0				\$7.2	
Site-10	medium	UNIT-3b	1 medium	\$100.0	\$40.0	\$180.0	\$360.0	\$252.0	\$7.2	\$266.4
		UNIT-2c	1 medium		\$40.0				\$7.2	
Total		UNIT-4d	1 medium		\$40.0		\$5,840	\$4,088	\$7.2	\$4,385
		# UNITS	20						\$297	

Table 3-6b. Estimate of net present value and rate of return for commercial treatment plant deployment with and without use of MWMF (DOE complex).

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
System demonstrated Facility deployed		1,2a	2b,2c	3a, 3b, 4a 1, 2, 9	4b, 4c, 4d 10	5a, 5b 3, 8	6a, 6b	7a, 8a 4	8b	9a, 10a 5, 6	11a 7	
MWMF capital Costs												
DWTF facility costs	(\$25.6)											
MWMF operations cost		(\$2.5)	(\$2.5)	(\$2.5)	(\$2.5)	(\$2.5)	(\$3.0)	(\$3.0)	(\$3.0)	(\$3.0)	(\$3.0)	(\$3.5)
MWMF demonstrations cost		(\$15.6)	(\$24.2)	(\$21.8)	(\$31.4)	(\$21.7)	(\$21.8)	(\$24.3)	(\$19.4)	(\$17.0)	(\$24.3)	(\$4.9)
Facility commercialization with MWMF					(\$1,148.0)	(\$252.0)	(\$896.0)		(\$448.0)		(\$896.0)	(\$448.0)
Facility commercialization without MWMF					\$1,640.0	\$360.0	\$1,280.0		\$640.0		\$1,280.0	\$640.0
Total Annual (Cost) Savings	(\$40.6)	(\$18.1)	(\$26.7)	(\$24.3)	\$458.1	\$83.8	\$359.2	(\$27.3)	\$169.6	(\$20.0)	\$356.7	\$183.6

Discount rate	Net present value
3%	\$1,135
4%	\$1,048
5%	\$968
6%	\$895
7%	\$829

Internal Rate of Return = 78%

construction. This element may have the largest impact on the ROI and is probably the least objective in the evaluation. Facility construction can run on the order of \$400M to \$600M for the size of facilities being evaluated. If such a facility is built, and is not allowed to be put into service for its intended use, the total cost (or a significant portion) would be "credited" to the MWMF as cost avoided, significantly increasing the cost savings for deployed facilities.

Case 1c. Non-Incineration States Only (Alternate Approach)

An alternative approach to evaluating the benefit of MWMF demonstrations on commercial deployment is to assess the risk of deployment without pilot-scale demonstrations vs. completing the demonstrations in the MWMF. The increased risk will be manifested by two primary factors: (1) it will increase the preoperational costs and reduce plant operational efficiency, and (2) it may lead to deploying technologies that will not meet the intended use.

Factor 1. ROI by the use of the MWMF can be calculated by evaluating the pre-operations cost savings with and without the use of integrated pilot-scale demonstrations to resolve operational issues. These costs would cover the time from completion of plant construction to the point at which the facility is ready for waste treatment operations, including having all permits in place and all evaluations and preoperational testing completed. With the MWMF to resolve technical and regulatory issues on the process technology and waste stream selection prior to deployment, it is

assumed that the start-up of operations can be essentially cut in half for a typical plant and that the operations can be made more efficient (assume by 5% to 10%) as a result of improved facility design and operations planning. These estimates are based on observed improvements in the engineering scale-up realized in the MWMF and on the coordination of system design, construction, and demonstrations with industrial partners who would be involved with subsequent plant construction and operations. Additionally, working with regulatory agencies and the public in resolving critical issues prior to plant deployment will further improve system acceptance and permitting.

The ITTS study (Ref. 2), *Planning life-cycle cost estimates for the ITTS study—Phase 2 systems*, addresses the total life-cycle cost for deploying various types of alternative systems. They break costs down into seven elements:

- 1.0 Studies and bench-scale test costs.
- 2.0 Demonstration costs.
- 3.0 Production facility construction costs.
- 4.0 Operations-funded activities.
- 5.0 Operating and maintenance.
- 6.0 Decontamination and decommissioning.
- 7.0 ROM life-cycle costs (20 years of operation).

Based on this report, "Preparation for Operations" (cost element 4.4 of Ref. 2), they estimate that the cost of preoperational testing is equivalent to the "Operating and Maintenance" costs for a year. In the MWMF evaluation for facility start-up and activation cost elements, we also found this estimate to be reasonably accurate. Further, while operations and maintenance costs will vary depending on the complexity of the plant and the types of wastes to be treated, the ratio of production facility costs (ITTS Study element 3.0) to the annual operating and maintenance costs (ITTS Study element 5.6) is reasonably constant at 13% (see Table 3-7). Using this ratio and the estimate for plant costs (based on Table 3-4) for the plants to be deployed at the NIS sites, we can estimate savings for start-up and activation and improvements in operations (see Table 3-8).

Table 3-7. Operating and maintenance costs as a ratio of facility construction cost (from reference 2).

ITTS Study system designation	Treatment facility construction cost	Annual operating & maintenance cost	Ratio of annual operations cost to facility cost
	(\$M)	(\$M)	
A-1	573	68.6	0.12
A-2	555	69.5	0.13
A-3	561	68.3	0.12
A-4	576	73.8	0.13
A-5	510	68.1	0.13
A-6	588	71.0	0.12
A-7	474	60.9	0.13
B-1	566	76.7	0.14
C-1	482	65.7	0.14
C-2	515	66.7	0.13
C-3	498	60.5	0.12
D-1	644	80.7	0.13
E-1	569	72.1	0.13
F-1	577	73.4	0.13
H-1	588	72.3	0.12
J-1	475	61.7	0.13
K-1	487	63.2	0.13
L-1	505	64.5	0.13
Average	541.3	68.8	0.127

For the small to medium facilities evaluated, the start-up cost ranges from \$17M to \$56M. Typical start-up cost savings (50%) of \$9M to \$28M are realized per plant. In addition, improvements in operations of approximately 7.5% over 20 years results in additional costs savings of \$27M to \$84M for each facility.

Based on a 20-year schedule of operations for each facility, and deployment of facilities consistent with MWMF demonstrations, the NPV is \$64M with a rate of return of 10%.

Factor 2. The second factor can result in the design and construction of treatment facilities that are not capable of handling the intended waste streams, that require major modifications prior to full-scale operations, or that—due to the lack of public acceptance—cannot be operated after construction. This element may have the largest impact on the ROI and is probably the least objective in the evaluation. Facility construction can run on the order of \$130M to \$370M for the size of facilities being evaluated. If such a facility is built and is not allowed to be put into service for its intended use, the total cost (or a significant portion) would be credited to the MWMF as cost avoided. Depending on the number of such facilities, this could potentially double or triple the net cost benefit of using the MWMF for pilot-scale demonstrations prior to

full-scale deployment. While such costs have major impact on the bottom line of this analysis, they are only identified here qualitatively.

3.2 Case 2: MWMF Demonstrations vs. Independent Site Demonstrations

Estimate the cost benefit of deploying UNITs using MWMF for coordinated, integrated pilot-scale demonstrations prior to deployment vs. independent demonstrations at the selected site.

This case deals solely with the cost effectiveness of demonstrating technologies in the MWMF—a single testbed site—vs. independent demonstrations at various locations, and is explicitly related to the number of technologies to be demonstrated. Independent of the demonstration location, these systems will require engineering scale-up, evaluation, regulatory approval, public acceptance, and industry involvement prior to effective deployment in a treatment plant. Two specific cases were investigated. In Case 2a, the deployment of adequate technologies to support the treatment needs of the non-incinerator states was evaluated. In the follow-on case, Case 2b, the number of technologies was expanded to cover the DOE complex under the assumption that incineration was no longer an accepted option for mixed waste treatment complexwide.

Table 3-8a. Start-up and operations improvements by pilot-scale demonstration prior to system deployment (commercial deployment in NISs).

			Without MWMF demonstrations			With MWMF demonstrations			
Site	Uncontingent treatment plant cost	Commercialization costs from pre-conceptual design	Start-up and activation (see Table B7)	20-year operating costs (20x annual operating)	Start-up and 20 years operations	Start-up and activation w/efficiency gains	20-year operating costs w/efficiency gains	MWMF operations and demonstration costs	Start-up and 20 years operations
	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M
MWMF Project and Infrastructure						Start-up Gains 50%	Operations Gains 8%		
MWMF Operations								40.6	
Site-1	\$160.0	\$320.0	\$40.7	\$814.2	\$854.9	\$20.4	\$753.1	21.5	\$802.7
Site-2	\$70.0	\$140.0	\$17.8	\$356.2	\$374.0	\$8.9	\$329.5	14.6	\$345.6
Site-3	\$70.0	\$140.0	\$17.8	\$356.2	\$374.0	\$8.9	\$329.5	14.6	\$353.0
Site-4	\$220.0	\$440.0	\$56.0	\$1,119.5	\$1,175.5	\$28.0	\$1,035.6	14.6	\$1,107.4
Site-5	\$200.0	\$400.0	\$50.9	\$1,017.8	\$1,068.7	\$25.4	\$941.4	14.6	\$995.9
Site-6	\$140.0	\$280.0	\$35.6	\$712.4	\$748.1	\$17.8	\$659.0	14.6	\$691.4
Total					\$4,595.2			14.6	\$4,358.1

Table 3-8b. Estimate of net present value and internal rate of return for improved efficiencies resulting from pilot-scale demonstrations (commercial deployment in NISs).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
System Demonstrated			1, 2a	2b	3a, 4a	4b	5a, 6a	6b	7a, 8a																				
Facility Site Deployed			3	2	1		4		5, 6																				
MWMP Capital Costs	(25.6)																												
DWTF Facility Costs	(15.0)																												
MWMP Operations Cost		(2.5)	(2.5)	(2.5)	(2.5)	(2.5)	(3.0)	(3.0)	(3.0)																				
MWMP Demonstrations Cost		(14.6)	(19.4)	(17.0)	(19.4)	(17.0)	(19.4)	(17.0)	(14.6)																				
Facility Start-up with MWMP			(8.9)	(8.9)	(20.4)		(28.0)		(43.3)																				
Facility Operations with MWMP				(16.5)	(33.0)	(70.6)	(70.6)	(122.4)	(122.4)	(202.4)	(202.4)	(202.4)	(202.4)	(202.4)	(202.4)	(202.4)	(202.4)	(202.4)	(202.4)	(202.4)	(202.4)	(202.4)	(202.4)	(185.9)	(169.5)	(131.8)	(131.8)	(80.0)	(80.0)
Facility Start-up without MWMP			17.8	17.8	40.7		56.0		86.5																				
Facility Operations without MWMP				17.8	35.6	76.3	76.3	132.3	132.3	218.8	218.8	218.8	218.8	218.8	218.8	218.8	218.8	218.8	218.8	218.8	218.8	218.8	218.8	201.0	183.2	142.5	142.5	86.5	86.5
Total Annual (Cost) Savings (\$M)	(40.6)	(17.1)	(13.0)	(9.3)	1.1	(13.8)	11.3	(10.1)	35.6	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	15.1	13.7	10.7	10.7	6.5	6.5

Discount Rate	Net Present Value (\$M)
3%	\$114
4%	\$87
5%	\$64
6%	\$46
7%	\$31

Internal Rate of Return = 10%

Case 2a: Non-incinerator States only—CA, NM, CO, and OH.

The fourth column of Table 3-1 shows an estimate of the number of treatment processes and facilities anticipated to effectively handle the volume of waste in the NISs. To meet the diversity of waste treatment needs, three or four different types of processes are likely to be deployed (aqueous liquids/slurries, organic liquids, organic homogeneous solids, and heterogeneous and organic debris), and about 11 processes in all.

As described in the ITTS Study, Ref. 2, design and construction of waste treatment facilities is preceded by both "Studies and Bench-Scale Tests" (item 1.0 of the ITTS Study) and technology "Demonstration" (item 2.0 of ITTS Study). Both of these activities are central to the MWMF demonstration plans. During the design phase of a demonstration technology, we include "Engineering Development" elements to resolve outstanding technical issues associated with scale-up engineering of the systems, and once the systems are constructed, there will be a detailed technology demonstration phase in which operational issues are addressed and system capabilities are evaluated.

By using a facility designed for pilot-scale demonstration and evaluation purposes, we avoid the cost of constructing and operating many independent demonstration facilities and systems. Further, since the facility infrastructure for safety and process system evaluations is in place, along with an experienced technical support staff, demonstration costs will be significantly reduced.

We assume that "equivalent" demonstration activities *must* be completed either within the MWMF or completed independently prior to construction of a treatment facility. As such, costs associated with "Studies and Bench Scale Tests" (element 1.0 of the ITTS Study) and construction through decommissioning (elements 3.0 through 7.0 of the ITTS Study) would be independent of the use of MWMF.* The cost benefit is based solely on the cost of independent pilot-scale studies, testing, and demonstration vs. use of the MWMF facility for the same functions.

Table 3-9 summarizes the cost breakdown as presented in the ITTS report and the associated estimates assuming the MWMF is integrated into the demonstration element of plant deployment. The project management and other associated costs for the MWMF facility and infrastructure are folded into the cost analysis as a separate item and are costed in "Year 0."† Once a technology is demonstrated in the MWMF or elsewhere, it may be deployed at multiple sites by completing additional demonstrations on waste streams of interest at the alternative sites. However, because the system is in place and the operations team assembled, significant additional equipment will not have to be procured nor operations staff trained in the new process.

* The costs identified for the "1.0 Studies and Bench Scale Tests" appear high. However, details were not available to evaluate this element. It is believed that the use of the MWMF could significantly reduce this element cost, but this benefit is not folded into the ROI estimate presented here.

† The MWMF costs are as follows:

Conventional facility	\$16M
(including Phase 2 DWTF and associated site and management costs)	
MWMF infrastructure	\$38M
(including MWMF Project cost minus demonstration elements)	

In this case, virtually the whole cost of demonstration can be recovered except for the actual manpower and equipment necessary to conduct the specific tests for the additional site. Costs for these additional demonstrations are estimated to be \$7.2M (\$3.6M demonstration manpower + \$3.6M additional miscellaneous expenses). To account for the same level of cost benefit for demonstration of a previously tested technology at an independent site, the ITTS Study costs were reduced from \$37.15M to \$10.7M. In this analysis, "non-deployed" technologies are treated the same as the deployed technologies since demonstration in the MWMF or an independent facility will result in the same data and avoid cost of full-scale deployment.

Figure 3.2 plots the costs associated with demonstrations in the MWMF, independent facilities, and the net benefit as a function of processes deployed. For this analysis, it is assumed that the initial technology is started at the beginning of year 1, and that a new technology or additional demonstration of a current technology is started every six months. Every fourth demonstration is delayed six months to allow for facility functions not associated with a specific demonstration (see Table 3-10). Additionally, it is assumed that every other technology will be evaluated for deployment at two facilities. The MWMF project is approximately 18 months ahead of deployment of site-specific independent demonstrations. Since this evaluation is based on a schedule relative to start of demonstration, this advantage for the MWMF is not factored into the analysis but would further increase the net cost benefit.

Based on the assumptions discussed and estimates presented (11 treatment demonstrations, 8 different technologies, deployed at least 5 sites), the net present value (NPV) ranges from \$80M to \$105M depending on the assumed discount rate (3% to 7%). For a discount rate of 5%, the NPV is \$92M. Further, based on the expected cost and savings, an annual internal rate of return has been calculated at 50%.

Case 2b: DOE Complexwide.

Using the approach described for Case 2a, we expand the number of demonstrations and duration of demonstration to correlate to deployment throughout the complex. Figure 3.3 plots the demonstration costs with and without the MWMF and the benefits realized from centralized demonstrations. As with Case 2a, costs for independent pilot-scale demonstrations are spread over 18 months, and the cost for demonstrating a previously evaluated technology is reduced (both for the MWMF and independent demonstrations) to reflect expected cost savings. Differing from Case 2a, in which 8 technology are distributed over 8 years, additional technologies are demonstrated to cover the broader spectrum of waste treatment needs. In this case 20 demonstrations of 11 different processes are conducted over the first 11 years of MWMF operations including 5 processes that are demonstrated for deployment at multiple sites. Table 3-11 is an extension of Table 3-10. It delineates how the demonstrations are distributed over the first 11 years of MWMF operations. The NPV for a 5% discount rate in this case is \$140M. The annual rate of return is 55%.

Table 3-9. Estimated costs associated with pilot-scale demonstrations of mixed waste treatment systems prior to plant construction.

	w/o MWMF (per ITTS Study, Table 4.1)	w/ MWMF operations and demonstration costs
Cost component	Cost (\$k)	Cost (\$k)
2.0		
2.1 Manpower/Demonstration	\$7,050	\$3,600
2.2 Design (note 3)	\$4,500	(incl.)
2.3 Inspection (note 3)	\$1,100	(incl.)
2.4 Project Mngt./Facility Ops (note 4)	\$1,500	\$2,500
2.5 Construction		
2.5.1 Building	\$2,200	
2.5.2 Equipment	\$7,400	\$7,400
2.5.3 Indirect	\$3,600	\$3,600
2.6 Construction Mgt. (note 3)	\$2,600	(incl.)
2.7 Management Reserve (note 3)	\$1,200	(incl.)
2.8 Contingency (note 3)	\$6,000	(incl.)
Subtotal 2.0	\$37,150	\$17,100

Figure 3.2. Cost-benefit analysis of demonstrations in the MWMF vs. use of independent demonstration sites, non-incineration states only.

Table 3-10. MWMF demonstration cost-benefit analysis for deployment to NISs.

	Year 0		Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8	
	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M
Facility																		
MWMF Facility & Infrastructure	\$40.6																	
Facility Operations			\$2.5		\$2.5		\$2.5		\$2.5		\$2.5		\$3.0		\$3.0		\$3.0	
Technology Demonstrations																		
UNIT-1 (MSO)																		
UNIT-2																		
UNIT-2, second site																		
UNIT-3																		
UNIT-4																		
UNIT-4, second site																		
UNIT-5																		
UNIT-6																		
UNIT-6, second site																		
UNIT-7																		
UNIT-8																		
Mixed Waste Management Facility																		
Semiannual totals	\$40.6	\$0.0	\$7.4	\$9.7	\$14.6	\$7.3	\$9.8	\$9.7	\$14.6	\$7.3	\$9.8	\$9.7	\$15.1	\$7.3	\$10.3	\$9.7	\$12.7	\$4.9
Cumulative total	\$40.6	\$40.6	\$48.0	\$57.7	\$72.3	\$79.6	\$89.4	\$99.1	\$113.7	\$121.0	\$130.8	\$140.5	\$155.6	\$162.9	\$173.2	\$182.9	\$195.6	\$200.5
Independent Demonstrations																		
Semi-annual Costs			\$12.4	\$24.8	\$28.3	\$15.9	\$15.9	\$24.8	\$28.3	\$15.9	\$15.9	\$24.8	\$28.3	\$15.9	\$15.9	\$24.8	\$24.8	\$12.4
Cumulative total			\$12.4	\$37.2	\$65.5	\$81.4	\$97.3	\$122.1	\$150.4	\$166.4	\$182.3	\$207.1	\$235.4	\$251.3	\$267.2	\$292.0	\$316.8	\$329.2

Summary of Annual Cost for Rate of Return Analysis

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
MWMF Capital Costs	\$(25.6)								
DWTF Facility Costs	\$(15.0)								
MWMF Operations Cost		\$ (2.5)	\$ (2.5)	\$ (2.5)	\$ (2.5)	\$ (2.5)	\$ (3.0)	\$ (3.0)	\$ (3.0)
MWMF Demonstrations Cost		\$(14.6)	\$(19.4)	\$(17.0)	\$(19.4)	\$(17.0)	\$(19.4)	\$(17.0)	\$(14.6)
Independent Demonstrations Cost Avoided		\$ 37.2	\$ 44.3	\$ 40.7	\$ 44.3	\$ 40.7	\$ 44.3	\$ 40.7	\$ 37.2
Total Annual (Cost) Savings	\$(40.6)	\$ 20.1	\$ 22.4	\$ 21.2	\$ 22.4	\$ 21.2	\$ 21.9	\$ 20.7	\$ 19.6

Discount Rate	Net Present Value \$M
3%	\$105
4%	\$98
5%	\$92
6%	\$86
7%	\$80

Internal Rate of Return = 50%

Figure 3.3. Cost-benefit analysis of demonstrations in the MWMF vs. use of independent demonstration sites, DOE complexwide.

3.3 Case 3. Shipping Waste vs. Deploying Treatment

Estimate the cost benefit of deploying UNITs in the NISs vs. shipping all waste to incineration sites.

This case provides for an alternative in which *no new facilities* are constructed for waste treatment in the NISs, and existing waste inventories are shipped to incineration sites in other states. It is difficult to estimate since it depends on many factors that cannot be easily quantified, nor does it address the ongoing operations of the DOE sites beyond the current waste-treatment needs. To provide comparison to this shipping alternative, the cost for building treatment facilities in the NISs is taken from Case 1a. Case 1a looks at commercial deployment of systems in the NISs that will address the current and ongoing needs of the impacted DOE sites. In

Table 3-11. Return-on-investment analysis for deployment of UNITs throughout the DOE complex.

	Year 0	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9		Year 10		Year 11	
	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M	\$M
Facility																							
MWME Facility & Infrastructure	\$40.6																						
Facility Operations			\$2.5		\$2.5		\$2.5		\$2.5		\$2.5		\$3.0		\$3.0		\$3.0		\$3.0		\$3.0		\$3.5
Technology Demonstrations																							
UNIT-1 (MSO)																							
UNIT-2																							
UNIT-2, second site																							
UNIT-2, third site																							
UNIT-3																							
UNIT-3, second site																							
UNIT-4																							
UNIT-4, second site																							
UNIT-4, third site																							
UNIT-4, fourth site																							
UNIT-5																							
UNIT-5, second site																							
UNIT-6																							
UNIT-6, second site																							
UNIT-7																							
UNIT-8																							
UNIT-8, second site																							
UNIT-9																							
UNIT-10																							
UNIT-11																							
Mixed Waste Management Facility																							
Semiannual totals	\$40.6	\$0.0	\$7.4	\$10.7	\$17.0	\$27.1	\$12.2	\$19.4	\$14.5	\$14.6	\$27.7	\$15.1	\$10	\$15.1	\$12.1	\$15.1	\$7.3	\$10.3	\$27.7	\$17.6	\$27.7	\$8.4	\$0.0
Cumulative total	\$40.6	\$40.6	\$48.0	\$58.7	\$75.7	\$85.4	\$97.6	\$109.7	\$129.1	\$143.6	\$158.2	\$167.8	\$183.0	\$193	\$207.8	\$219.9	\$235.0	\$242.3	\$252.6	\$262.3	\$279.9	\$289.6	\$298.0
Independent Demonstrations																							
Semiannual Demonstration totals			\$12.4	\$24.8	\$31.9	\$19.5	\$19.5	\$28.3	\$35.4	\$24.6	\$23.0	\$19.5	\$28.3	\$19.5	\$28.3	\$28.3	\$15.9	\$15.9	\$24.8	\$37.2	\$24.8	\$12.4	\$0.0
Cumulative total			\$12.4	\$37.2	\$69.0	\$88.5	\$108.0	\$136.3	\$171.7	\$196.3	\$221.3	\$240.8	\$269.1	\$288.6	\$316.9	\$345.3	\$373.6	\$399.5	\$405.4	\$430.2	\$467.4	\$492.1	\$504.5

Summary of Annual Costs for Rate of Return Analysis

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
MWME Capital Costs	(\$25.6)											
DWTF Facility Costs	(\$15.0)											
MWME Operations Cost		(\$2.5)	(\$2.5)	(\$2.5)	(\$2.5)	(\$3.0)	(\$3.0)	(\$3.0)	(\$3.0)	(\$3.0)	(\$3.0)	(\$3.5)
MWME Demonstrations Cost		(\$15.6)	(\$24.2)	(\$21.8)	(\$31.4)	(\$21.7)	(\$21.8)	(\$24.3)	(\$19.4)	(\$17.0)	(\$24.3)	(\$4.9)
Independent Demonstrations Cost		\$37.2	\$51.4	\$47.8	\$62.0	\$42.5	\$47.8	\$56.6	\$44.3	\$40.7	\$61.9	\$12.4
Total Annual (Cost) Savings	(\$40.6)	\$19.1	\$24.7	\$23.5	\$28.1	\$18.3	\$23.0	\$29.4	\$21.9	\$20.7	\$34.6	\$4.0

Discount Rate	Net Present Value
	\$M
3%	\$163
4%	\$151
5%	\$140
6%	\$130
7%	\$121

Internal Rate of Return = 55%

Table 3-4a, the cost estimate for building treatment plants and deploying technologies at six sites is calculated. The cost for this option, including the MWMF distributed costs, is \$1,400M.

To evaluate the cost for shipping waste to other states for treatment, estimates were obtained from the Hazardous Waste Management (HWM) Division of LLNL (Ref. 5). In the estimate provided, HWM used the liquid organic waste streams as the basis since there is ongoing activity (shipments of these streams to DSSI) that could be well quantified. Their analysis included transportation, analytical requirements, LLNL labor, and disposal costs. They did not consider indirect costs such as facility, regulatory compliance, maintenance, or LLNL overheads. Based on their analysis, we estimate the cost for off-site treatment to be \$10 to \$12/kg. Assuming that the density of these materials is approximately 1 g/cm³, this results in a cost of ~\$10,000/m³. Assuming that the overhead costs will add another 50% to 100% to the identified costs, and that the handling of solids (including repackaging, certification, and volume inefficiencies) further increases the estimate by approximately 50%, the total estimated cost for off-site shipment and treatment is estimated to be approximately \$30,000/m³. The current inventory of incinerable waste in the NISs that require shipment and treatment is shown in Table 3-1. The total volume of current waste is ~6,600 m³. Based on this number, the cost for shipping and treating is ~\$200M. This compares to the estimate presented earlier of \$1,400M for developing and deploying non-incineration technologies at six sites within the NISs. The cost differential for this evaluation is therefore ~\$1200M (cost favors incineration), however a number of non-tangible risk factors have not been fully addressed including, for instance, the viability of incineration for continued operations within the DOE complex, risk of shipping mixed waste, and state agreements.

3.4 Sensitivity Analysis

As a result of the input from the MWFA, EM-50, and EM-30 reviews, we expanded the study to consider a broader range of assumptions. Table 3-12 describes the "base" case assumptions and a summary of results considered in the analysis described earlier in Section 3. Table 3-13 provides a similar pair of tables for a "low" case excursion. In the low-case analysis, we minimized the net benefit of the MWMF by reducing the anticipated benefits from demonstration in the MWMF and reducing the costs associated with independent demonstrations. The results of this and other study excursions are the basis for the study ranges identified in Table 1 of the Executive Summary.

The two primary factors influencing the net cost benefit from this study are (1) the cost for building a treatment facility and (2) the cost for independent site demonstrations. Clearly, if treatment facility costs are very low, then the impact for demonstrating technologies and reducing the risk for subsequent full-scale

Table 3-12a. Input parameters for case study cost-benefit analysis base-case input data.

Facility size	Infrastructure cost (\$M)	Treatment process	UNIT cost (\$M)
Small	\$50	Small	\$20
Medium	\$100	Medium	\$40
Large	\$180	Large	\$100

Contingency	Percent	Efficiency gains start-up	Efficiency gains operations
Pre-conceptual	100%		
Preliminary Design	40%	50%	8%

Demonstration costs (from Table B2)	(\$M)	Facility and infrastructure costs	(\$M)
MWMF - first site	\$14.6	MWMF pre FY96	\$12.2
MWMF - additional sites	\$7.2	MWMF cost-to-go	\$25.6
Independent demonstration - first site	\$37.2	DWTF Phase 2 pre-FY96	\$1.0
Independent demonstration - additional sites	\$10.7	DWTF Phase 2 cost-to-go	\$15.0
MWMF operations (annual)	\$2.5	Total	\$53.8

deployment will be diminished. Similarly, if the cost for conducting fully integrated demonstrations of new process systems at independent sites is low, then the benefit of consolidating some of these demonstrations at a centralized site designed for treatment demonstrations will be reduced. To address the impact of these two important factors, we conducted two separate sensitivity analyses. First, we reduced the cost of independent site demonstrations by reducing the required infrastructure cost and operations overhead. Second, we reduced the cost of small and mid-size treatment facility construction so as to reduce the impact of cost savings from pilot-plant demonstrations.

Figure 3.4 addresses the impact of reducing the cost of deploying successful demonstrations into full-scale treatment facilities. The abscissa of this plot is the expected infrastructure cost to build a treatment plant. The cost numbers shown on the abscissa and associated with each of the data curves are for a small, medium, and large plant or process units as defined in Tables 3-2 and 3-3. For this analysis, we varied only the cost of the small and medium facilities. The costs shown to the right of the plot represent the base case for plant infrastructure costs. The plotted data are for the two specific analysis cases 1a and 1c, in which the cost benefit is related to the reduction of contingency for plant construction and to improvements in start-up

Table 3-12b. Summary of results from case study cost-benefit analysis base-case output results.

	Net present value, \$M (5% discount rate)	Internal rate of return (annual)
Case 1a—Commercial deployment with and without pilot-scale demonstrations (based on contingency risk reduction); NIS	\$210	44%
Case 1b—Commercial deployment with and without pilot-scale demonstrations; complexwide.	\$968	78%
Case 1c—Commercial deployment with and without pilot-scale demonstrations (based on start-up and operations efficiencies)	\$64	10%
Case 2a—MWMF demonstrations vs. Independent site demonstrations; NIS	\$92	50%
Case 2b—MWMF demonstrations vs. Independent site demonstrations; complexwide	\$140	55%

	Cost difference between options
Case 4—Ship all MLLW to incineration sites for processing vs. building treatment options in non-incineration states.	(\$1,205)

and operations costs, respectively. As would be expected, as the cost for building and operating treatment plants is reduced, the benefit for doing any pilot-scale studies is reduced. This would be true whether the pilot-scale demonstrations were conducted in the MWMF or at independent sites. The base case plant costs were generated from the ITTS study and MWMF cost studies for conceptual and preliminary design.

The cost of technology demonstrations is addressed in Figure 3.5. The MWFA commented that the cost for independent site demonstrations as taken from the ITTS study (ref. 2) may not be a realistic estimate of the actual cost for these demonstrations. They felt that the costs for demonstrations could be significantly reduced. Figure 3.5 addresses two aspects of the technology demonstrations: first, the cost for the facility infrastructure for completing fully integrated demonstrations is varied from \$5M to

\$25M. Second, since we anticipate that treatment demonstrations will be conducted in the MWMF as well as at some selected independent sites, we develop a scenario in which approximately half of the demonstrations are conducted in the MWMF and the other half at sites currently planned through the MWFA. Based on these assumptions, it appears that an infrastructure cost of about \$10M for independent site demonstrations is the breakeven for the cost benefit. As independent site demonstrations become more costly, the benefit leans more in favor of a centralized facility. For comparison, the cost for the demonstration facility infrastructure (including operations and overhead manpower) developed in the ITTS study, Phase 2 report is ~\$23M, as shown by the dashed line in Figure 3.5. Further, if the cost for a centralized facility can be reduced, the breakeven cost will be further reduced below \$10M.

Table 3-13a. Input parameters for case study cost-benefit analysis low-case input data.

Facility size	Infrastructure cost (\$M)	Treatment process	UNIT cost (\$M)
Small	\$25	Small	\$20
Medium	\$50	Medium	\$50
Large	\$100	Large	\$80

Contingency	Percent	Efficiency gains start-up	Efficiency gains operations
Pre-conceptual	100%		
Preliminary design	40%	25%	6%

Demonstration costs (from Table B2)	(\$M)	Facility and infrastructure costs	(\$M)
MWMF - first site	\$14.6	MWMF pre FY96	\$12.2
MWMF - additional sites	\$7.2	MWMF cost-to-go	\$25.6
Independent demonstration - first site	\$28.2	DWTF Phase 2 pre-FY96	\$1.0
Independent demonstration - additional sites	\$7.2	DWTF Phase 2 cost-to-go	\$15.0
MWMF operations (annual)	\$2.5	Total	\$53.8

Table 3-13b. Summary results from case study cost-benefit analysis low-case output results.

	Net present value, \$M (5% discount rate)	Internal rate of return (annual)
Case 1a—Commercial deployment with and without pilot-scale demonstrations (based on contingency risk reduction); NIS	\$130	30%
Case 1b—Commercial deployment with and without pilot-scale demonstrations; complexwide.	\$651	64%
Case 1c—Commercial deployment with and without pilot-scale demonstrations (based on start-up and operations efficiencies)	(\$38)	2%
Case 2a—MWMF demonstrations vs. Independent site demonstrations; NIS	\$29	21%
Case 2b—MWMF demonstrations vs. Independent site demonstrations; complexwide	\$46	24%

	Cost difference between options
Case 4—Ship all MLLW to incineration sites for processing vs. building treatment options in non-incineration states.	(\$953)

Figure 3.4a. Plant cost sensitivity analysis, net-present-value.

Figure 3.4b. Plant cost sensitivity analysis, internal rate of return.

Figure 3.5a. Demonstration cost sensitivity analysis: independent site facility infrastructure cost (Net Present Value).

Figure 3.5b. Demonstration cost sensitivity analysis: independent site facility infrastructure cost (Internal Rate of Return).

4.0 References

1. *Fourth Interim Report, Integrated Thermal Treatment System Study, Phase 1 Results*, Feizollahi, Quapp, Hempill, and Groffie, INEL, EGG-MS-11211, May 1994.
2. *Second Draft, Integrated Thermal Treatment System Study, Phase 2 Results*, Feizollahi and Quapp, INEL, LITCO-MS-11211, October 1994.
3. *MWMF Project Baseline 2.0* (to be published).
4. *Integrated Data Base Report—1994: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections and Characteristics*, DOE/RW-0006, Rev. 11, September 1995.
5. J. Bowers, LLNL, private communications.
6. *Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants*, Merrow, Phillips, and Myers, Rand Corp., R-2569-DOE, September 1981.

Appendix A: Cost-Benefit Analysis for the MWMF at LLNL

Science Applications International Corporation

Following is the SAIC document analyzing the return-on-investment and cost benefit of the MWMF.

Science Applications International Corporation
An Employee-Owned Company

February 14, 1996

Mr. Ronald Streit, L-276
Lawrence Livermore National Laboratory
P. O. Box 808
Livermore, CA 94550

Subject: Benefit-Cost Analysis for MWMF

Reference: LLNL Contract No. B304270
SAIC Project 01-0337-07-3308-001

Dear Ron:

Enclosed is the Benefit-Cost analysis for the Mixed Waste Management Facility (MWMF) provided by Mr. Frank Augustine of SAIC's Environmental Technology R&D Operations. This report is submitted to provide information requested by the Department of Energy on the potential return on investment (ROI) of the MWMF. This analysis follows OMB Circular No. A-94 "Guidelines and Discount rates for Benefit-Cost Analysis of Federal Programs", and considers three alternatives: Under Alternative One, no test bed is constructed at LLNL. Under Alternative Two, the MWMF is constructed including telerobotic equipment. Under Alternative Three, the MWMF is constructed without telerobotics. For these analyses Alternative Two has the lowest net present value. This analysis is based on assumptions which are reasonable in principle, and includes a sensitivity analysis for variations in the value of key assumptions.

If you have any questions or comments, please contact me at (510) 463-8111, extension 2141.

Sincerely,

A.A. DiSabatino

Encl.: a/s

cc: F. Augustine, SAIC
Correspondence File 2.1

P. Densley, L-276

BENEFIT-COST ANALYSIS FOR THE PROPOSED MWMF AT LLNL

INTRODUCTION

Lawrence Livermore National Laboratory (LLNL) is proposing a Mixed Waste Management Facility (MWMF), composed of two primary elements; the MWMF Project and the Decontamination and Waste Treatment Facility (DWTF) Phase 2 facility construction. The MWMF would test and validate technologies for processing low-level mixed wastes. As a National Test Bed established for this purpose, the MWMF expects to facilitate and accelerate the achievement of the Department of Energy's mixed waste treatment/destruction goals by: standardizing technical evaluations, accumulating data to be used in permitting applications made to federal and state regulatory agencies, conducting economic analyses and verifying claimed costs, reducing technical risks, determining optimum treatment trains, and identifying environmental safety and health considerations associated with deployment of the various treatment systems that may be installed at sites throughout the DOE complex after successful testing and validation at the MWMF.

The treatment of Mixed Waste, at present, is limited to a very few geographical locations and a range of treatment costs per cubic foot of waste that are not principally driven by technical factors, but rather by economic motives (limited supply/high demand= very profitable) and somewhat arbitrary fee considerations (including state surcharges). New treatment facilities identified in the Comprehensive Site Treatment Plans (CSTP's) prepared by DOE are likely to require treatments other than incineration (flame combustion in the presence of oxygen). The efficacy of incinerators to destroy the hazardous constituent of mixed waste is not an issue; rather it is public opposition to incineration based on the potential for fugitive emissions of dioxins and furans that exists in incineration systems which are exhausted to the environment. Such fugitive emissions result when temperatures fluctuate outside relatively narrow optimum ranges due to incomplete mixing, inhomogeneity in waste streams, and the simultaneous presence of certain problematic chemicals, principally chlorine.

The public opposition to incineration has already delayed important national programs, such as the US Army's destruction of chemical warfare agents and slowed, or stopped, the issuance of incinerator permits by the U.S. Environmental Protection Agency.

There is, therefore, a concerted effort to discover, develop, and deploy viable and cost effective incineration alternatives. The technologies proposed to date for consideration in lieu of incineration are based on a wide variety of physical, chemical, and biological principles and exist in the range from theory to lab-scale, pilot scale, field-scale, to full (commercial) scale. Most, however, have not been configured for, or adapted to, mixed waste treatment.

Among the non-incineration alternatives which have been identified as possible MWMF "clients" are:

1. Gas Phase Chemical Reduction Process
2. Acid Digestion
3. DELPHI Detox
4. Direct Chemical Oxidation
5. Mediated Electrochemical Oxidation
6. Wet Air Oxidation
7. Wet Oxidation
8. Molten metal
9. Molten Salt oxidation
10. Thermal Desorption
11. Soil washing

Of these, Molten Salt Oxidation has been chosen as the first treatment technology that will be tested in the MWMF.

It and the other technologies named are the most "promising" candidates that may lead to successful treatment systems. There are a number of others in varying stages of development that have not been listed here.

A National Test Bed, where these proposed technologies could be fairly and thoroughly evaluated and compared, will result in the confident deployment of at least some significant fraction of the technologies tested which, in turn, will foster competitive treatment alternatives compared to the present, limited-option, situation. The effect of competition will be to close the gap in the demand-supply relationship and lower the costs to the government for treatment/destruction/disposal of mixed waste. The proliferation of treatment options, geographically, will alleviate the problems associated with costly and problematic transport of hazardous waste to far-removed treatment sites and deflect the opposition to treatment at locations far removed from the site of the waste generation or storage but in someone else's backyard (NIMBY).

In commercial enterprises where investment decisions are required to be based on the prospects of future sales of goods and/or services, a Return-on-Investment (ROI) analysis is customarily conducted. The analysis of government investment decisions cannot proceed in the manner that private sector ROI would because of the differing conditions under which the government operates. The Office of Management and Budget has, therefore, promulgated instead a guideline for the conduct of Cost-Benefit Analyses; since the key objective for the government is the wise investment of monies to save additional expenditures later, or to achieve some other recognized "good", for example removal or reduction of future liability.

This report provides a Benefit-Cost Analysis for the proposed MWMF at LLNL that takes these factors into consideration, and which quantifies them to the extent

possible. A more rigorous investigation could be undertaken to further fine-tune the assumptions and gather the data necessary to accurately determine cost implications and relationships to key assumptions. However, for this report the sensitivity of the results to changes in four of the most important variables was examined. The analysis follows OMB Circular No. A-94 "Guidelines and Discount rates for Benefit-Cost Analysis of Federal Programs." OMB No. A-94 states:

"The goal of this Circular is to promote efficient resource allocation through well-informed decision-making by the Federal Government. It provides general guidance for conducting benefit-cost and cost-effectiveness analyses. It also provides specific guidance on the discount rates to be used in evaluating Federal programs whose benefits and costs are distributed over time. The general guidance will serve as a checklist of whether an agency has considered and properly dealt with all the elements for sound benefit-cost and cost-effectiveness analyses."

This analysis considers that the combination of mixed waste presently in inventory and that projected for future generation is incapable of being diminished in a timely manner by existing treatment facilities. Existing treatments are either not suitable for all the waste streams that must be treated, or have insufficient capacity to timely dispose of those that it can. The paucity of treatment systems and locations favors, in an economic sense, those few existing commercial treatment facilities who are free to a remarkable degree to charge whatever the market will bear.

It is reasonable to speculate that ANY move by the government to increase the supply of treatment facilities will affect the supply-demand relationship which currently favors the present owners of the few treatment facilities. While the preparation by individual sites of waste treatment plans could have had, in and of itself, such a desired effect; the economic and regulatory realities and the present political interest in privatization of services strongly indicate that the ambitious goals set forth in the site CSTP's are unlikely to be achieved on schedule. DOE management, by its own admission, has adjusted its cleanup timetables and cost expectations radically upward from those which it had projected in 1990.

It is interesting to note that the extension of time also tends to eliminate the use of incineration as a treatment technology for waste elimination, due to increasing public opposition to any form of incineration, as well as to the proliferation of competitive incineration alternatives that are perceived to be more environmentally benign. While treatment systems based on incineration could be considered to add capacity, it is unrealistic to expect that any new incineration plants will be constructed in the near future.

The analysis considers three alternatives. Under Alternative One, no test bed is constructed at LLNL. Under Alternative Two, the MWMF is constructed including tele-robotic equipment. Under Alternative Three, the MWMF is constructed

without tele-robotics. Alternative Two has the lowest net present value (NPV) and is the recommended option from a benefit-cost perspective. However, the whole analysis is based on assumptions which are tentative and have some uncertainty. In principle, they are eminently reasonable.

ASSUMPTIONS

LLNL is requesting funding from DOE in the amount of \$68 million. The \$68 million is composed of construction of the Decontamination and Waste Treatment Facility (DWTF), MWMF Infrastructure, Tele-robotic sorting, and Molten Salt Oxidation (MSO) deployment.

Construction of the DWTF includes design, site preparation, construction, management activities, and activation of the conventional facility in which to house the MWMF demonstration testbed. It is a component of the total DWTF Project - a Congressional Line item. Although the facility for the MWMF is integrated with a number of other elements of the DWTF Project, its attributable cost is approximately \$16 million.

MWMF Infrastructure includes the construction of the integrated testbed. The cost includes:

- receiving and shipping
- conventional feed preparation
- water treatment
- final forms
- supervisory instrumentation and controls
- process diagnostic services
- project management activities
- ES&H oversight
- QA
- permitting and environmental documentation
- start-up and activation of all systems
- public participation, and
- project integration

The total cost for MWMF Infrastructure, including amounts spent in past fiscal years is approximately \$38 million.

Tele-robotic sorting is a feed preparation demonstration system. It has an additional cost of \$3 million.

MSO deployment includes the initial cost of the first demonstration technology for testing. It has a cost of \$11 million.

Table 1 presents each cost by fiscal year:

Table 1
Capital Costs
(Thousands of FY96 Dollars)

	FY93	FY94	FY95	FY96	FY97	FY98	FY99	Total
DWTF Phase 2 Facility	0	0	1,000	2,000	12,000	1,000	0	16,000
MWMF Infrastructure	500	7,300	4,400	4,100	8,400	9,200	3,900	37,800
MWMF TRS	0	100	900	900	0	1,300	200	3,400
MWMF MSO	0	400	2,000	4,200	3,300	1,200	0	11,200

Approximately \$16.6 million of total costs has been expended prior to FY96. In accordance with OMB No. A-94, this "sunk" cost is excluded from the analysis. The \$16.6 million would be a transfer, not an incremental cost or benefit.

The cost for "basic" operation of the MWMF is estimated at \$2.5 million per year. This cost includes a qualified operations team, ES&H oversight, facility maintenance, training, and LLNL space charges. In addition to the basic operating cost, the operation of each primary process technology will incur an operating cost estimated at \$4 million. This cost includes installation and integration, detailed test plans, testing, process diagnostics, and decommissioning and removal of equipment. The analysis assumes that basic operating costs are incurred beginning in FY96 and that test operations costs are incurred beginning in FY98.

LLNL proposes to charge the vendors of each technology approximately \$2 million to reimburse the Government for the costs of testing. LLW also proposes to direct a part of its expected future appropriated funding to the MWMF. Each of these charges or funding plans represent a transfer payment rather than a cost or cost savings and is not included in this benefit-cost analysis.

The analysis assumes that testing of the first technology (MSO) would begin in FY98. Technologies would be tested consecutively (one at a time) and each test would require 18 months. The analysis assumes that 12 technologies would be tested and that 8 would proceed to implementation.

Alternatives Two and Three are expected to result in a variety of cost savings and benefits. Some of the cost savings or benefits identified are directly attributable to:

- An accelerated schedule for implementation of technologies
- Facilitation and acceleration of permit application and issuance
- Early selection of optimized treatment trains for the particular technology
- Reduced risk for vendors and the Government
- Increased price competition among vendors resulting in economic efficiency
- Elimination or reduction of the need for long-term MW storage, frequent, periodic monitoring, and inventory
- Elimination or reduction of risk and liability attached to long-term storage, exposure of personnel, and possibility of natural or man-made calamities.

These cost savings or benefits are intangible or difficult to quantify and project. The benefit-cost analysis attempts to capture these cost savings or benefits quantitatively through several simple assumptions. The analysis assumes that two of every three technologies are validated and go on to implementation, adding 170,000 annual cubic feet of processing capacity each to the total industry. With each capacity increase, the model assumes that the average cost per cubic foot is reduced by 5 percent. If each of the intangibles above were to contribute a mere 1 percent reduction in treatment cost per cubic foot, a 5 percent figure is a reasonable assumption, and in any case, less than the marginal cost per cubic foot to maintain the waste in storage. The model can be exercised to demonstrate the sensitivity of the results to different cost-benefit assumptions.

Alternative Three makes the same assumptions but reduces cost per cubic foot by only 4 percent with each capacity increase.

RESULTS

The data and assumptions for the MWMF are inputs to a simple benefit-cost model developed as a Lotus 1-2-3 spreadsheet. The format of the model follows sample formats developed by OMB. Since Alternatives Two and Three project only incremental costs, Alternative One has a net present value of zero. No detailed tables are presented for Alternative One.

Alternative Two has a net present value of -\$360 million. This negative cost represents a net savings in costs over the life cycle of the MWMF. Table 2 presents the results of the benefit-cost analysis. Each cost element is projected in constant FY96 dollars across the 20 year term of analysis. The period of analysis is semi-annual in order to accommodate the 18 month schedule for testing technologies. Total Cost is the sum in each year across the cost elements. In order to account for the time-value of money, the net present value of total costs is calculated. Mid-year discount factors are computed using an annual real discount rate of 4.9 percent. The product of the Total Cost in each year and the discount factor for each year is the Discounted Total Cost. The sum of the Discounted Total Cost across years is the net present value (NPV) of the alternative.

Table 2
Cost/Benefit Analysis
Alternative Two - Build a Test Bed with Tele-Robotics
(Thousands of Constant FY96 Dollars)

Fiscal Year	Share of DWTF Facility	MWMF Infra-structure	Tele-Robotics	MSO Deploy-ment	Basic Oper-ations	Test Oper-ations	Cost Savings	Total Cost	Mid-Year Discount Factors	Discounted Total Cost
1996	2,000	4,100	900	4,300	1,250		0	12,550	0976	12,253
					1,250		0	1,250	0953	1,192
1997	12,000	8,400	0	3,300	1,250		0	24,950	0931	23,222
					1,250		0	1,250	0909	1,136
1998	1,000	9,200	1,300	1,200	1,250	1,333	0	15,283	0887	13,561
					1,250	1,333	0	2,583	0866	2,238
1999	0	3,900	200	0	1,250	1,333	0	6,683	0846	5,653
					1,250	1,333	(3,640)	(1,057)	0826	(873)
2000					1,250	1,333	(3,640)	(1,057)	0806	(852)
					1,250	1,333	(3,640)	(1,057)	0787	(832)
2001					1,250	1,333	(8,756)	(6,172)	0769	(4,744)
					1,250	1,333	(8,756)	(6,172)	0750	(4,632)
2002					1,250	1,333	(8,756)	(6,172)	0733	(4,523)
					1,250	1,333	(8,756)	(6,172)	0715	(4,416)
2003					1,250	1,333	(8,756)	(6,172)	0699	(4,311)
					1,250	1,333	(8,756)	(6,172)	0682	(4,210)
2004					1,250	1,333	(15,232)	(12,649)	0666	(8,423)
					1,250	1,333	(15,232)	(12,649)	0650	(8,224)
2005					1,250	1,333	(15,232)	(12,649)	0635	(8,030)
					1,250	1,333	(22,964)	(20,381)	0620	(12,632)
2006					1,250	1,333	(22,964)	(20,381)	0605	(12,333)
					1,250	1,333	(22,964)	(20,381)	0591	(12,042)
2007					1,250	1,333	(22,964)	(20,381)	0577	(11,757)
					1,250	1,333	(22,964)	(20,381)	0563	(11,479)
2008					1,250	1,333	(22,964)	(20,381)	0550	(11,208)
					1,250	1,333	(31,852)	(29,268)	0537	(15,715)
2009					1,250	1,333	(31,852)	(29,268)	0524	(15,344)
					1,250	1,333	(31,852)	(29,268)	0512	(14,981)
2010					1,250	1,333	(41,802)	(39,219)	0500	(19,600)
					1,250	1,333	(41,802)	(39,219)	0488	(19,137)
2011					1,250	1,333	(41,802)	(39,219)	0476	(18,684)
					1,250	1,333	(41,802)	(39,219)	0465	(18,243)
2012					1,250	1,333	(41,802)	(39,219)	0454	(17,812)
					1,250	1,333	(41,802)	(39,219)	0443	(17,391)
2013					1,250	1,333	(52,731)	(50,147)	0433	(21,711)
					1,250	1,333	(52,731)	(50,147)	0423	(21,198)
2014					1,250	1,333	(52,731)	(50,147)	0413	(20,697)
					1,250	1,333	(64,556)	(61,973)	0403	(24,973)
2015					1,250	1,333	(64,556)	(61,973)	0393	(24,382)
					1,250	1,333	(64,556)	(61,973)	0384	(23,806)
Sum	15,000	25,600	2,400	8,800	50,000	48,000	(945,165)	(795,365)		(359,937)

Table 3 presents detail on the phasing assumptions for Alternative Two. The start for testing of each technology is 18 months apart. Every third technology is assumed to be rejected for implementation. Industry capacity begins with the current level of 558,000 cubic feet per year and grows after each technology is approved. The analysis makes no assumptions concerning where wastes could be produced, stored, or transported. Wastes are generated at a rate of 1,000,000 cubic feet per year so that the existing inventory of waste initially grows above its current level of 3,600,000 cubic feet. The source for current inventories and waste production is the US Department of Energy Overview of Proposed Site Treatment Plans, March 31, 1995. Volumes have been converted from cubic meters to cubic feet to ease calculations using commercial treatment costs which have been quoted in dollars per cubic foot.

Table 3
Cost/Benefit Analysis
Alternative Two - Build a Test Bed with Tele-Robotics

Fiscal Year	Start Technology	Approve Technology	Add Cu Ft Capacity	Industry Cu Ft Capacity	Cu Ft Waste Generated	Cu Ft Waste Inventory
1996				279,000	500,000	3,821,000
				279,000	500,000	4,042,000
1997				279,000	500,000	4,263,000
				279,000	500,000	4,484,000
1998	1			279,000	500,000	4,705,000
				279,000	500,000	4,926,000
1999		1		279,000	500,000	5,147,000
	2		85,000	364,000	500,000	5,283,000
2000				364,000	500,000	5,419,000
		2		364,000	500,000	5,555,000
2001	3		85,000	449,000	500,000	5,606,000
				449,000	500,000	5,657,000
2002		X		449,000	500,000	5,708,000
	4			449,000	500,000	5,759,000
2003				449,000	500,000	5,810,000
		3		449,000	500,000	5,861,000
2004	5		85,000	534,000	500,000	5,827,000
				534,000	500,000	5,793,000
2005		4		534,000	500,000	5,759,000
	6		85,000	619,000	500,000	5,640,000
2006				619,000	500,000	5,521,000
		X		619,000	500,000	5,402,000
2007	7			619,000	500,000	5,283,000
				619,000	500,000	5,164,000
2008		5		619,000	500,000	5,045,000
	8		85,000	704,000	500,000	4,841,000
2009				704,000	500,000	4,637,000
		6		704,000	500,000	4,433,000
2010	9		85,000	789,000	500,000	4,144,000
				789,000	500,000	3,855,000
2011		X		789,000	500,000	3,566,000
	10			789,000	500,000	3,277,000
2012				789,000	500,000	2,988,000
		7		789,000	500,000	2,699,000
2013	11		85,000	874,000	500,000	2,325,000
				874,000	500,000	1,951,000
2014		8		874,000	500,000	1,577,000
	12		85,000	959,000	500,000	1,118,000
2015				959,000	500,000	659,000
		X		959,000	500,000	200,000
Sum			680,000	23,400,000	20,000,000	

Table 4 presents detail on the calculation of cost savings for Alternative Two. Cost savings are calculated on an initial average rate of \$200 per cubic foot. This unit cost is not expected to change in real (non-escalated) dollars if no MWMF is constructed. The product of the cost savings per cubic foot and the waste processed in each year is the total cost savings in each year. For example, in the second half of FY99, the implementation of a new, validated technology results in an industry-wide cost reduction to the federal government of \$10 per cubic foot. Since total industry production in that 6 month period is 364,000 cubic feet, the cost savings is

$$\$10 \times 364,000 = \$3,640,000$$

Table 4
Cost/Benefit Analysis
Alternative Two - Build a Test Bed with Tele-Robotics

Fiscal Year	Approve Techno -logy	Percent Cost Reduction	Average Cost Per Cu. Ft.	Savings Per Cu. Ft.	Cu. Ft. Waste Capacity	Total Cost Savings (Thousands)
1996			\$200	\$0	279,000	\$0
			\$200	\$0	279,000	\$0
1997			\$200	\$0	279,000	\$0
			\$200	\$0	279,000	\$0
1998			\$200	\$0	279,000	\$0
			\$200	\$0	279,000	\$0
1999	1		\$200	\$0	279,000	\$0
		5%	\$190	\$10	364,000	\$3,640
2000	2		\$190	\$10	364,000	\$3,640
		5%	\$190	\$10	364,000	\$3,640
2001			\$181	\$20	449,000	\$8,756
			\$181	\$20	449,000	\$8,756
2002			\$181	\$20	449,000	\$8,756
			\$181	\$20	449,000	\$8,756
2003			\$181	\$20	449,000	\$8,756
	3		\$181	\$20	449,000	\$8,756
2004		5%	\$171	\$29	534,000	\$15,232
			\$171	\$29	534,000	\$15,232
2005	4		\$171	\$29	534,000	\$15,232
		5%	\$163	\$37	619,000	\$22,964
2006			\$163	\$37	619,000	\$22,964
			\$163	\$37	619,000	\$22,964
2007			\$163	\$37	619,000	\$22,964
			\$163	\$37	619,000	\$22,964
2008	5		\$163	\$37	619,000	\$22,964
		5%	\$155	\$45	704,000	\$31,852
2009			\$155	\$45	704,000	\$31,852
	6		\$155	\$45	704,000	\$31,852
2010		5%	\$147	\$53	789,000	\$41,802
			\$147	\$53	789,000	\$41,802
2011			\$147	\$53	789,000	\$41,802
			\$147	\$53	789,000	\$41,802
2012			\$147	\$53	789,000	\$41,802
	7		\$147	\$53	789,000	\$41,802
2013		5%	\$140	\$60	874,000	\$52,731
			\$140	\$60	874,000	\$52,731
2014	8		\$140	\$60	874,000	\$52,731
		5%	\$133	\$67	959,000	\$64,556
2015			\$133	\$67	959,000	\$64,556
			\$133	\$67	959,000	\$64,556
Sum					23,400,000	945,165

Alternative Three has a net present value of -\$277 million. Table 5 presents the costs of Alternative Three. No cost is projected for the acquisition of tele-robotic equipment but the cost savings projected are lower than in Alternative Two. The result is a higher net cost to the Government. Table 6 presents detail on the phasing assumptions for Alternative Three. Table 7 presents detail on the calculation of cost savings for Alternative Three.

Table 5
Cost/Benefit Analysis
Alternative Two - Build a Test Bed WITHOUT Tele-Robotics
(Thousands of Constant FY96 Dollars)

Fiscal Year	Share of DWTF Facility	MWMF Infrastructure	Tele-Robotics	MSO Deployment	Basic Operations	Test Operations	Cost Savings	Total Cost	Mid-Year Discount Factors	Discounted Total Cost
1996	2,000	4,100		4,300	1,250		0	11,650	0976	11,375
					1,250		0	1,250	0953	1,192
1997	12,000	8,400		3,300	1,250		0	24,950	0931	23,222
					1,250		0	1,250	0909	1,136
1998	1,000	9,200		1,200	1,250	1,333	0	13,983	0887	12,407
					1,250	1,333	0	2,583	0866	2,238
1999	0	3,900		0	1,250	1,333	0	6,483	0846	5,484
					1,250	1,333	(2,912)	(329)	0826	(271)
2000					1,250	1,333	(2,912)	(329)	0806	(265)
					1,250	1,333	(2,912)	(329)	0787	(259)
2001					1,250	1,333	(7,040)	(4,457)	0769	(3,426)
					1,250	1,333	(7,040)	(4,457)	0750	(3,345)
2002					1,250	1,333	(7,040)	(4,457)	0733	(3,266)
					1,250	1,333	(7,040)	(4,457)	0715	(3,189)
2003					1,250	1,333	(7,040)	(4,457)	0699	(3,113)
					1,250	1,333	(7,040)	(4,457)	0682	(3,040)
2004					1,250	1,333	(12,310)	(9,727)	0666	(6,477)
					1,250	1,333	(12,310)	(9,727)	0650	(6,324)
2005					1,250	1,333	(12,310)	(9,727)	0635	(6,175)
					1,250	1,333	(18,651)	(16,068)	0620	(9,959)
2006					1,250	1,333	(18,651)	(16,068)	0605	(9,723)
					1,250	1,333	(18,651)	(16,068)	0591	(9,493)
2007					1,250	1,333	(18,651)	(16,068)	0577	(9,269)
					1,250	1,333	(18,651)	(16,068)	0563	(9,050)
2008					1,250	1,333	(18,651)	(16,068)	0550	(8,836)
					1,250	1,333	(25,996)	(23,412)	0537	(12,571)
2009					1,250	1,333	(25,996)	(23,412)	0524	(12,274)
					1,250	1,333	(25,996)	(23,412)	0512	(11,984)
2010					1,250	1,333	(34,281)	(31,697)	0500	(15,841)
					1,250	1,333	(34,281)	(31,697)	0488	(15,467)
2011					1,250	1,333	(34,281)	(31,697)	0476	(15,101)
					1,250	1,333	(34,281)	(31,697)	0465	(14,744)
2012					1,250	1,333	(34,281)	(31,697)	0454	(14,396)
					1,250	1,333	(34,281)	(31,697)	0443	(14,055)
2013					1,250	1,333	(43,447)	(40,864)	0433	(17,692)
					1,250	1,333	(43,447)	(40,864)	0423	(17,273)
2014					1,250	1,333	(43,447)	(40,864)	0413	(16,865)
					1,250	1,333	(53,437)	(50,854)	0403	(20,492)
2015					1,250	1,333	(53,437)	(50,854)	0393	(20,008)
					1,250	1,333	(53,437)	(50,854)	0384	(19,535)
Sum	15,000	25,600	0	8,800	50,000	48,000	(774,139)	(626,739)		(276,723)

Table 6
Cost/Benefit Analysis
Alternative Two - Build a Test Bed WITHOUT Tele-Robotics

Fiscal Year	Start Technology	Approve Technology	Add Cu. Ft. Capacity	Industry Cu. Ft. Capacity	Cu. Ft. Waste Generated	Cu. Ft. Waste Inventory
1996				279,000	500,000	3,821,000
				279,000	500,000	4,042,000
1997				279,000	500,000	4,263,000
				279,000	500,000	4,484,000
1998	1			279,000	500,000	4,705,000
				279,000	500,000	4,926,000
1999		1		279,000	500,000	5,147,000
	2		85,000	364,000	500,000	5,283,000
2000				364,000	500,000	5,419,000
		2		364,000	500,000	5,555,000
2001	3		85,000	449,000	500,000	5,606,000
				449,000	500,000	5,657,000
2002		X		449,000	500,000	5,708,000
	4			449,000	500,000	5,759,000
2003				449,000	500,000	5,810,000
		3		449,000	500,000	5,861,000
2004	5		85,000	534,000	500,000	5,827,000
				534,000	500,000	5,793,000
2005		4		534,000	500,000	5,759,000
	6		85,000	619,000	500,000	5,640,000
2006				619,000	500,000	5,521,000
		X		619,000	500,000	5,402,000
2007	7			619,000	500,000	5,283,000
				619,000	500,000	5,164,000
2008		5		619,000	500,000	5,045,000
	8		85,000	704,000	500,000	4,841,000
2009				704,000	500,000	4,637,000
		6		704,000	500,000	4,433,000
2010	9		85,000	789,000	500,000	4,144,000
				789,000	500,000	3,855,000
2011		X		789,000	500,000	3,566,000
	10			789,000	500,000	3,277,000
2012				789,000	500,000	2,988,000
		7		789,000	500,000	2,699,000
2013	11		85,000	874,000	500,000	2,325,000
				874,000	500,000	1,951,000
2014		8		874,000	500,000	1,577,000
	12		85,000	959,000	500,000	1,118,000
2015				959,000	500,000	659,000
		X		959,000	500,000	200,000
Sum			680,000	23,400,000	20,000,000	

Table 7
Cost/Benefit Analysis
Alternative Two - Build a Test Bed WITHOUT Tele-Robotics

Fiscal Year	Approve Technology	Percent Cost Reduction	Average Cost Per Cu. Ft.	Savings Per Cu. Ft.	Cu. Ft. Waste Capacity	Total Cost Savings (Thousands)
1996			\$200	\$0	279,000	\$0
			\$200	\$0	279,000	\$0
1997			\$200	\$0	279,000	\$0
			\$200	\$0	279,000	\$0
1998			\$200	\$0	279,000	\$0
			\$200	\$0	279,000	\$0
1999	1		\$200	\$0	279,000	\$0
		4%	\$192	\$8	364,000	\$2,912
2000			\$192	\$8	364,000	\$2,912
	2		\$192	\$8	364,000	\$2,912
2001		4%	\$184	\$16	449,000	\$7,040
			\$184	\$16	449,000	\$7,040
2002			\$184	\$16	449,000	\$7,040
			\$184	\$16	449,000	\$7,040
2003			\$184	\$16	449,000	\$7,040
	3		\$184	\$16	449,000	\$7,040
2004		4%	\$177	\$23	534,000	\$12,310
			\$177	\$23	534,000	\$12,310
2005			\$177	\$23	534,000	\$12,310
	4		\$170	\$30	619,000	\$18,651
2006		4%	\$170	\$30	619,000	\$18,651
			\$170	\$30	619,000	\$18,651
2007			\$170	\$30	619,000	\$18,651
			\$170	\$30	619,000	\$18,651
2008			\$170	\$30	619,000	\$18,651
	5		\$163	\$37	704,000	\$25,996
2009		4%	\$163	\$37	704,000	\$25,996
			\$163	\$37	704,000	\$25,996
2010			\$157	\$43	789,000	\$34,281
	6		\$157	\$43	789,000	\$34,281
2011		4%	\$157	\$43	789,000	\$34,281
			\$157	\$43	789,000	\$34,281
2012			\$157	\$43	789,000	\$34,281
	7		\$157	\$43	789,000	\$34,281
2013		4%	\$150	\$50	874,000	\$43,447
			\$150	\$50	874,000	\$43,447
2014			\$150	\$50	874,000	\$43,447
	8		\$144	\$56	959,000	\$53,437
2015		4%	\$144	\$56	959,000	\$53,437
			\$144	\$56	959,000	\$53,437
Sum				23,400,000	774,139	

Sensitivity Analysis

In the benefit-cost analysis presented above, all of the input parameters were set to our best judgment. This section presents the sensitivity of the results to changes in four of the most important variables. Table 8 presents the sensitivity analysis in tabular form.

Table 8
Sensitivity Analysis

Discount Rate		
Range	NPV of Alt. 2	NPV of Alt. 3
2.00%	(573,849)	(448,449)
2.60%	(520,788)	(405,802)
3.20%	(472,789)	(367,248)
3.80%	(429,328)	(332,364)
4.40%	(389,944)	(300,774)
4.90%	(359,937)	(276,723)
5.60%	(321,795)	(246,174)
6.20%	(292,334)	(222,598)
6.80%	(265,545)	(201,180)
7.40%	(241,167)	(181,705)
8.00%	(218,964)	(163,985)

Capital Cost Underrun/Overrun		
Range	NPV of Alt. 2	NPV of Alt. 3
-10%	(364,720)	(281,285)
-7%	(363,046)	(279,688)
-3%	(361,372)	(278,092)
0%	(359,937)	(276,723)
4%	(358,024)	(274,898)
8%	(356,350)	(273,301)
11%	(354,676)	(271,704)
15%	(353,002)	(270,107)
18%	(351,328)	(268,510)
22%	(349,654)	(266,913)
25%	(347,980)	(265,316)

Cost Reduction with Tele-robotics		
Range	NPV of Alt. 2	NPV of Alt. 3
0.0%	108,526	(276,723)
1.0%	6,191	(276,723)
2.0%	(91,636)	(276,723)
3.0%	(185,146)	(276,723)
4.0%	(274,521)	(276,723)
5.0%	(359,937)	(276,723)
6.0%	(441,564)	(276,723)
7.0%	(519,563)	(276,723)
8.0%	(594,091)	(276,723)
9.0%	(665,299)	(276,723)
10.0%	(733,330)	(276,723)

Cost Reduction WITHOUT Tele-robotics		
Range	NPV of Alt. 2	NPV of Alt. 3
0.0%	(359,937)	106,325
0.9%	(359,937)	14,017
1.8%	(359,937)	(74,624)
2.7%	(359,937)	(159,737)
3.6%	(359,937)	(241,457)
4.0%	(359,937)	(276,723)
5.4%	(359,937)	(395,235)
6.3%	(359,937)	(467,538)
7.2%	(359,937)	(536,943)
8.1%	(359,937)	(603,560)
9.0%	(359,937)	(667,500)

Table 8 shows that the results of the analysis are robust. Alternative 2 remains the most cost-effective alternative except when the estimated cost savings falls below 2 percent per technology.