USE OF LIFE-CYCLE COST ESTIMATES IN THE EVALUATION OF PROPOSED WASTE-TREATMENT FACILITIES*

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ABSTRACT

This paper describes the use of life-cycle cost estimating to evaluate proposed waste management facilities. The Department of Energy (DOE) requirements related to life-cycle costs are discussed, the components of life-cycle cost are identified, and the application of the method to a proposed facility for treating low-level waste and low-level mixed waste at the DOE's Idaho National Engineering Laboratory is described. Life-cycle costs show clear differences from traditional cost methods and appear to provide a better basis for making funding decisions. Although a life-cycle estimate is more difficult to perform because it involves more elements, it should become easier in the future as a broader experience base is formed.

INTRODUCTION

The Department of Energy (DOE) is responsible for managing a large quantity of radioactive waste, hazardous waste, and mixed waste generated by defense and other activities over the past several decades. Enhanced capabilities are needed for the treatment, storage, and disposal of these wastes. New or modified facilities will be required at many of the DOE sites.

The financial investment in these facilities will be very substantial and comes at a time of close scrutiny of Federal budgets. It will be an important and challenging task for DOE to make sound decisions in determining which facilities to build and at which sites.

Numerous waste management alternatives need to be evaluated to ensure the most effective use of funds. For a decision concerning waste treatment at a given site, for example, the alternatives might include constructing a new facility, modifying any of several existing facilities, combining separate proposed facilities to perform multiple functions, making use of commercial treatment capabilities offsite, and using decentralized treatment at the individual waste-generation locations.

One important factor in evaluating alternatives is the cost. The DOE approach for planning and budgeting of new facilities has traditionally focused on the total estimated cost or the total project cost of a proposed facility. Such costs cover the activities from preconceptual studies through completion of construction and inspection.

This paper describes the use of a more comprehensive type of cost estimate in evaluating proposed waste management facilities, namely, life-cycle costs. Life-cycle costs cover all activities related to the entire life cycle of the facility, from preconceptual studies through decontamination and decommissioning (D&D). In addition, life-cycle costs encompass indirect cost impacts from the proposed facility on other site activities. For example, if one alternative waste-treatment facility would achieve more volume reduction of the waste than would another alternative facility, the operating costs of waste disposal may be reduced. The reduced disposal costs are captured in the life-cycle cost analysis, yielding a more comprehensive measure of the overall cost to the DOE.

This paper discusses the DOE requirements related to life-cycle costs, the components of life-cycle cost, application of the method to a proposed facility for treating low-level waste (LLW) and low-level mixed waste (LLMW) at the DOE's Idaho National Engineering Laboratory (INEL), and the conclusions drawn from this application.

REQUIREMENTS

The principal DOE Order governing projects to construct or modify facilities is DOE Order 4700.1, Project Management System. The Order covers all major areas, including categorization of projects, management responsibilities, work breakdown structures, budgeting, cost estimating, baseline management, reporting and assessment, construction management, etc.

The Order defines "life-cycle cost" as follows:

> The sum total of the direct, indirect, recurring, nonrecurring and other related costs incurred or estimated to be incurred in the design, development, production, operation, maintenance, support and final disposition of a major system over its anticipated useful life span. Where system or project planning anticipates use of existing sites or facilities, restoration and refurbishment costs should be included.

The Order also defines the types of cost estimates that are widely used. The "total estimated cost" (TEC) includes engineering, design, and construction costs. The "total project cost" (TPC) includes the TEC plus other project-related costs (e.g., research and development costs).

The Order recognizes seven classes of cost estimates. The classes vary primarily according to the phase of a project, from planning/feasibility study cost estimates at the beginning of a project to Title II design cost estimates at the completion of detailed design. Broad evaluations of waste management alternatives are best performed early in the project, so the estimates discussed hereafter are all planning/feasibility study cost estimates.

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Although DOE Order 4700.1 defines life-cycle cost, there is no explicit requirement therein to use such cost estimates. The Order does state that "the acquisition process requires that DOE management ... maintain a capability to ... estimate life-cycle costs during system design, concept evaluation and selection, full-scale development, facility conversion, and production to ensure appropriate tradeoffs among investment costs, operating costs, schedules, and performance." DOE Order 6430.1A, in Section 0285-2.2, "Recommended Practices," states that life-cycle cost analysis "shall be performed *during site* selection for TSD facilities."

Secretary of Energy Notice SEN-27-90, "Strengthening the Department of Energy Project Management System," strengthened DOE Order 4700.1, but added no requirements related to life-cycle cost estimating.

COMPONENTS OF LIFE-CYCLE COST

As its definition indicates, life-cycle costs include several components. Figure 1 illustrates the components, as applied to waste treatment facilities. Each component is described briefly below.

The "front-end" costs occur primarily at or near the early stages of a project. Many of these costs are not directly related to producing a new facility but are regulatory-related costs. Front-end costs include project management and preliminary studies (e.g., project definition, Functional and Operational Requirements, design support, and siting studies). Also included are costs for documentation such as National Environmental Policy Act (NEPA) documents and environmental permitting under the Clean Air Act, Clean Water Act, Toxic Substances Control Act (TSCA), and Resource Conservation and Recovery Act (RCRA). Also included are the costs of Safety Analysis Reports and environmental, safety, health, and quality compliance (ESH&Q) support. Research and Development (R&D) costs for technology development are also front-end costs.

Engineering, design and inspection costs include performance specifications, conceptual and Title I/II design and Title III inspection of all facilities necessary to the complete design of the project. These include buildings to house processing equipment, incidental areas (e.g., laboratories), waste storage buildings, etc.

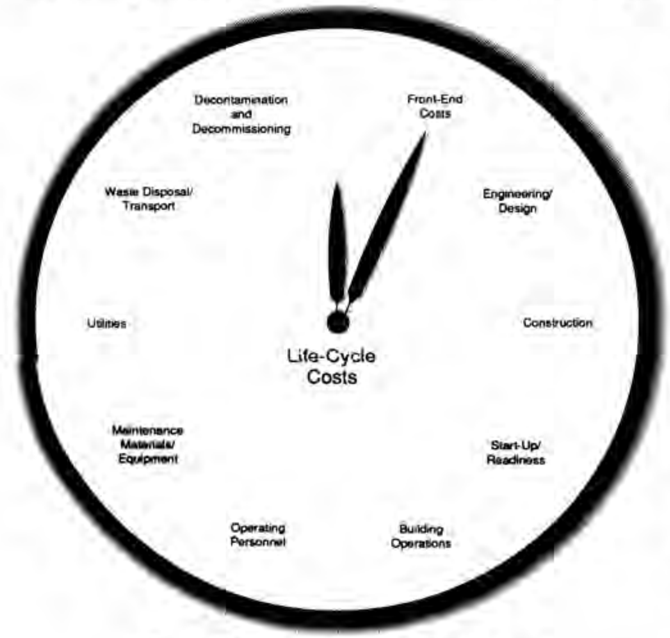

Fig. 1. Components of life-cycle cost.

Construction costs include improvements to land, site work, building construction, process equipment, and construction management (unique to the INEL).

Start-up and readiness review costs include initial system testing, operation and maintenance manuals, training of personnel, and the preparation for and conduct of contractor and DOE readiness reviews.

Operating costs include staff, materials, peripheral equipment, maintenance, and utilities. All costs need to reflect the full period of operation (e.g., 25 years).

For waste treatment facilities, many of the waste transport and disposal costs are indirect in nature, but are still included in life-cycle cost. Costs include the transport costs from the waste generator to the treatment facility, from the treatment facility to the disposal site, and disposal costs. Back-end (post-treatment) transport costs and disposal costs depend on the volume and weight of the treated waste, which in turn depends on the treatment processes.

D&D costs include D&D planning and operations, as well as the costs of managing the wastes generated during D&D.

Finally, contingency and management reserve are included.

APPLICATION OF LIFE-CYCLE COST METHODOLOGY

Background

The INEL is currently evaluating alternatives for the treatment of LLW and LLMW. In a preliminary study (1), eight alternatives were developed and compared. The eight alternatives, including the options within two of the alternatives, form a relatively complete set of twelve upper-level alternatives (Table I) ranging from no action (store the waste) to building a new treatment facility. Included are the modification and use of currently available facilities and the use of offsite facilities.

Each alternative was evaluated on several criteria. One criterion was to minimize the life-cycle cost.

Life-Cycle Cost Determination

Each alternative was evaluated to determine the costs in each cost category. The approach was to break down each category into cost elements and then to estimate the cost of each cost element. Information developed to describe each alternative, including schedule and facility and process descriptions, was used to define the elements and help in estimating the cost. The estimates were made using conventional estimating techniques (i.e., current information from vendors, engineering judgment based on costs of similar projects and facilities, costs reported in other studies, parametric studies).

Particular care was taken in the development of waste disposal costs. Calculated values for the disposal of a unit of waste (a 55-gallon drum was used for this study) have varied widely. Even for shallow land burial of contact-handled LLW at the existing Radioactive Waste Management Complex (RWMC) at the INEL, cost estimates ranging from \$1.49/ft^3 to \$56/ft^3 have been identified.

The wide range of estimated disposal costs arises mostly because different studies apportion different percentages of

TABLE I
Alternatives Evaluated for Treatment of INEL LLW and LLMW

Alternative 1	Construct and operate a new facility called the Mixed and Low-Level Waste Treatment Facility (MLLWTF). Both maximum and minimum treatment options were evaluated.
Alternative 2	Modify and operate the Waste Experimental Reduction Facility (WERF)
Alternative 3	Modify and operate the Process Experimental Pilot Plant (PREPP)
Alternative 4	Generator treatment of waste
Alternative 5	Treat waste at an offsite facility
Alternative 6	Treat LLW and LLMW in the Idaho Waste Processing Facility (IWPF)-a separate proposed facility for treatment of alpha-contaminated waste
Alternative 7	Combinations of alternatives WERF and Offsite treatment WERF and IWPF Generators and Offsite treatment Generators and IWPF
Alternative 8	No action (store LLMW indefinitely, dispose of LLW without treatment)

the fixed costs to the unit costs. It is important to understand which cost elements are appropriate to use in a given instance. For this study, incremental costs are recommended, but both incremental and fully apportioned costs were estimated. Incremental costs consider only the additional cost to the disposal facility of disposing of the waste and include none of the fixed costs. The fixed costs are considered a sunk cost, an expenditure that is made regardless of whether the additional waste is disposed of or not. The incremental cost developed for disposal of contact-handled LLW is $5.2/ft^3$, which is toward the bottom of the range mentioned earlier. Fully apportioned cost includes all sunk costs. The value developed for contact-handled waste is $24.7/ft^3$. (The evaluation of the results here is based on incremental costs only.) It is evident that selection of the appropriate unit cost for waste disposal can have a major impact on the life-cycle cost.

Life-Cycle Cost Results

The life-cycle cost estimates for each alternative are summarized in Table II. Subtotals for the eight cost categories are also shown.

The costs were developed in two forms. One form is escalated costs (year-of-expenditure). This form is used for budget purposes, although, as mentioned before, the estimates presented here are rough estimates and not budget quality. The other form, which is the form presented in Table II, is an approximation of present-worth equivalent costs. This form allows equivalence comparisons of alternatives whose expenditures occur at different times. Equivalence comparisons (present worth calculations) are necessary for a fair comparison of different money-time series.

The present-worth equivalent costs are graphically displayed in Fig. 2. Costs from all eight categories are included. Some combinations of categories are made, resulting in only five divisions on the bar-graph. The front-end costs and the engineering, design, and inspection costs are combined. Construction costs and startup and readiness costs are combined. Operating costs and waste transport and disposal costs are combined.

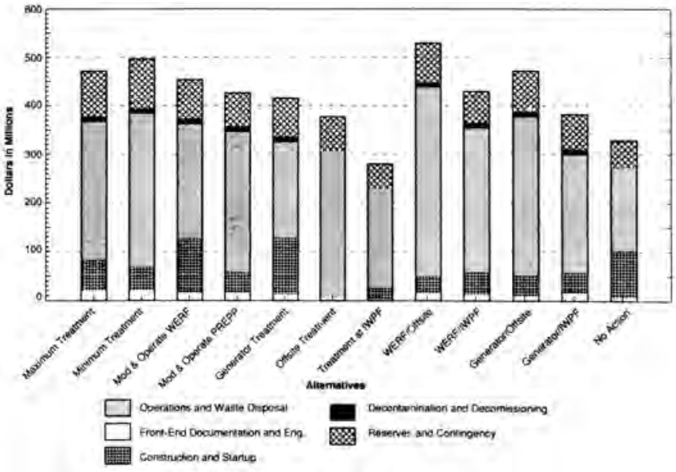

Fig. 2. Life-cycle costs – present-worth equivalent cost, FY-92.

POINTS OF INTEREST REVEALED THROUGH LIFE-CYCLE COSTS

Three points of particular interest are noted with respect to the life-cycle costs developed in this preliminary study: a) the effect of maximum waste treatment on life-cycle cost, b) the effect of offsite treatment on life-cycle cost, and c) the difference in cost ranking between life-cycle costs and traditional costs.

DOE Order 5820.2A, "Radioactive Waste Management," states in part that

> "Use of waste treatment techniques to increase the life of the disposal facility and improve the long-term facility performance, by improved site stability and reduction of infiltrating water, is required to the extent it is cost effective."

It was not known at the outset what level of treatment would be cost effective. To evaluate the effect of the level of treatment, two options were developed for the MLLWTF alternative. One option, maximum treatment, involves maximum volume reduction. All combustible waste is incinerated, all compactible waste is compacted, and all large waste items are reduced in size to allow more compact storage. In the other option, called minimum treatment, only waste that had to be thermally treated because of a regulatory requirement for hazardous waste treatment was incinerated. Compaction and size-reduction were not used.

It was expected that the minimum treatment option would be less expensive than the maximum treatment option. It was found, however, that the minimum treatment option was 5%

TABLE II

Summary of Life-Cycle Costs for the Treatment Alternatives--Present-Worth Equivalent Costs, FY-92 M$

Alternative	Up-front Cost[a]	Design Cost[b]	Construction Cost	Startup Cost	Operations Cost[c]	Waste Disposal Cost Inc.[d]	Waste Disposal Cost App.[e]	D&D Cost[f]	Reserves and Contingency Inc.	Reserves and Contingency App.	Total Cost[g] Inc.	Total Cost[g] App.
MLLWTF												
Maximum	20	11	44	8	247	40	125	7	93	115	470	575
Minimum	20	8	31	7	258	65	150	5	102	121	497	600
WERF	16	5	93	8	212	26	111	3	88	103	450	550
PREPP	16	7	22	8	247	40	125	3	78	99	422	527
Generator	13	5	102	4	150	42	126	5	88	109	410	515
Offsite	7	0	0	0	225	69	154	0	69	94	370	480
IWPF	4	0	14	0	137	65	149	0	51	73	270	377
Combinations												
WERF/Offsite	16	5	14	6	348	43	128	3	95	124	530	644
WERF/IWPF	16	5	28	6	251	40	125	3	81	94	428	525
Generator/Offsite	14	5	18	2	277	59	144	5	89	100	470	566
Generator/IWPF	13	5	32	2	186	55	140	5	72	97	370	480
No Action	9	3	90	2	104	50	134	1	72	98	330	441

a. Project management, NEPA, environmental permitting, safety analyses, technology demonstration, etc.
b. Includes waste storage buildings, as well as treatment facility. This applies to construction, startup, operations, and D&D costs, also.
c. Twenty-five years of operations.
d. Incremental costs (recommended disposal costs for use in this study). Includes transportation.
e. Apportioned (total) costs. Includes transportation.
f. Assumed D&D mode is total dismantlement.
g. Total may not exactly equal the sum of the parts due to round-off errors.

more expensive in life-cycle cost than the maximum treatment option. The savings in treatment equipment and associated operation was more than offset by the increase in disposal cost. This was true even though the incremental disposal cost was used. Thus, a waste form providing better confinement could be produced at a smaller life-cycle cost. Thus, in this comparison of two particular alternatives, increased treatment was found to be cost effective.

Another unexpected result was the competitive cost of offsite treatment. It was expected that the shipment costs would offset any cost advantages, but this was found not to be true. The benefit of not paying all of the facility sunk costs (they are apportioned to all customers) resulted in the offsite option being one of the least expensive.

It should be noted that the offsite option evaluated is comparable to the MLLWTF minimum-treatment option described previously. If a maximum-treatment option were used offsite, the additional unit cost of waste treatment plus the additional shipping costs would more than offset the waste disposal gain, and the life-cycle cost would be about $500 millon, comparable to the MLLWTF maximum-treatment option. Since the term "cost effective" is not clearly defined in DOE Order 5820.2A, it is not known if the expenditure of an additional $135 million to maximize treatment offsite is desirable.

It was expected that the rankings based on life-cycle cost would be different from those based on cost through startup. Table III shows the ranking of options based on the two different cost models and using present-worth equivalent costs. The rankings are much different. For life-cycle costs, the IWPF alternative is the cheapest and is 25% less expensive than its nearest competitor, no action. For the case of the traditional total project costs, the offsite alternative is the least expensive, with its closest competitor, treatment at IWPF, being two-and-one-half times more costly. Generally speaking, the rankings based on the two cost approaches are entirely different.

CONCLUSIONS

Life-cycle costs show clear differences from traditional cost methods and appear to provide a better basis for making funding decisions. A life-cycle estimate is more difficult to perform because it involves more elements. However, it should become easier in the future as a broader experience base is formed.

In conclusion, a) life-cycle cost estimates appear to give a truer picture of cost, (constraints associated with near-term funding cycles might not allow its use, however), b) disposal cost is a key element, even if incremental costs are used, c) the use of offsite facilities is competitive, even on a life-cycle cost basis, because the apportioned costs are spread out among numerous customers, and d) the term "cost effective," as used in DOE Order 5820.2A, needs further definition to allow consistent application.

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1. T.H. SMITH, W.S. ROESENER, M.J. JORGENSON-WATERS, and C.R. EDINBOROUGH, *A Preliminary Evaluation of Alternatives for Treatment of INEL Low-Level Waste and Low-Level Mixed Waste*, EGG-WMO-10321, Idaho National Engineering Laboratory (June 1992).