ESTIMATING AND UNDERSTANDING DOE WASTE MANAGEMENT COSTS

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ABSTRACT

This paper examines costs associated with cleaning up the U.S. Department of Energy's (DOE's) nuclear facilities, with particular emphasis on the waste management program. Life-cycle waste management costs have been compiled and reported in the DOE Baseline Environmental Management Report (BEMR). Waste management costs are a critical issue for DOE because of the current budget constraints. The DOE sites are struggling to accomplish their environmental management objectives given funding scenarios that are well below anticipated waste management costs. Through the BEMR process, DOE has compiled complex-wide cleanup cost estimates and has begun analysis of these costs with respect to alternative waste management scenarios and policy strategies. From this analysis, DOE is attempting to identify the major cost drivers and prioritize environmental management activities to achieve maximum utilization of existing funding. This paper provides an overview of the methodology DOE has used to estimate and analyze some waste management costs, including the key data requirements and uncertainties.

INTRODUCTION

The DOE is in the process of establishing plans and agreements to clean up its nuclear facilities that are spread across the country in what is commonly referred to as the "weapons
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complex." The weapons complex consists of laboratories, research facilities, testing areas, production plants, waste disposal sites, waste storage buildings, and a variety of support structures. The environmental legacy of the nuclear research, testing, and production activities includes: large quantities of several different types of hazardous, radioactive, and mixed (hazardous and radioactive) waste that need to be processed and disposed; contaminated sites that need to be cleaned up, stabilized, or restored; and a multitude of facilities that need to be decontaminated, decommissioned, or demolished. Collectively, these cleanup activities make up DOE's Environmental Management (EM) Program.

There are several organizational elements of the DOE EM Program. One of these is the Office of Waste Management (EM-30). EM-30 encompasses all of DOE's waste management activities, which include waste handling, storage, treatment, and disposal. Estimates have shown that the life-cycle costs of DOE's planned waste management activities represent almost one half of the total EM Program costs. One of the tools that has been developed by EM-30 to estimate and analyze some of DOE's waste management costs is the System Cost Model (SCM). This paper provides an overview of the data requirements for the SCM and identifies areas of uncertainty associated with data collected and modeling activities performed to date for EM-30. The issues and recommendations presented, although developed in reference to the SCM, can be considered generally applicable to any of DOE's waste management cost estimating and modeling activities.

BASELINE ENVIRONMENTAL MANAGEMENT REPORT

Total Program Estimate

The initial BEMR was submitted to Congress in March of 1995. This report provided a first ever look at DOE's potential total environmental liability. In order to account for all of the relevant total program costs, DOE had to establish a planning basis for the BEMR that encompassed the life-cycle of activities at each DOE site. The BEMR also forced DOE to integrate planning between the various programs (Waste Management—EM-30, Environmental
Restoration—EM-40, Technology Development—EM-50, and Facility Stabilization and Maintenance—EM-60). The total EM Program estimate includes not only the costs of each of these individual programs, but also the cost impacts resulting from interactions between the programs. For example, some EM-30 costs may be the result of treatment or disposal of waste generated by EM-40 or EM-60 activities.

Life-Cycle Cost Estimates

The total program estimate provided in the BEMR forecasts life-cycle costs for all planned environmental management activities necessary to cleanup DOE's approximately 130 sites. Life-cycle costs are those required to provide cradle-to-grave management of the wastes and facilities at the DOE sites. For the BEMR, the life-cycle was interpreted to be the time required to complete all environmental management activities related to the clean-up of legacy waste at each of the DOE sites. For most of the DOE sites, this life-cycle is expected to extend beyond the year 2020, and for some sites, beyond 2050.

The life-cycle encompasses all phases of a project or facility, including engineering studies, bench-scale testing, conceptual design, construction, startup, operations and maintenance, shutdown, and decommissioning. In the special case of disposal facilities, the life-cycle includes each of the elements listed above, along with closure and post-closure monitoring throughout the institutional control period.

Waste Management Activities

The EM-30 Program consists of all activities necessary for: 1) management of all DOE legacy waste, 2) management of waste generated by ongoing DOE activities, and 3) management of waste generated by EM-40 and EM-60. Cradle-to-grave waste management includes all activities between waste generation and final disposition. Typical waste management activities include the broad categories of pretreatment, storage, transportation, treatment, and disposal. Within each of these broad categories of waste management activities, there is a wide array of
specific processes, technologies, or functions. For a particular waste stream, a waste management plan will include all steps required for safe and compliant disposition. The waste management activities that are identified are based on the contaminant types and concentrations present in the waste stream, the form and characteristics of the waste stream, all applicable regulations, and a variety of “other factors.” Some of the “other factors” that influence waste management plans include: stakeholder concerns, political agreements, economics, health risks, schedules, residual/effluent quantities, etc.

**Role of System Cost Model in Baseline Environmental Management Report Process**

For the most part, the 1995 BEMR cost estimates were prepared by the individual DOE sites. However, in order to better understand the potential range of life-cycle costs of the total integrated EM Program, the DOE headquarters BEMR task force performed additional cost analyses. The sensitivity analyses were used to establish the variability of the total program estimate with respect to key programmatic strategies and decisions. This is an important aspect of the BEMR because the out-year planning basis is so speculative. Rather than have the sites estimate life-cycle costs for several different scenarios, DOE developed and applied models that were calibrated based on the site baseline estimates. The SCM was used in these analyses to estimate life-cycle costs of waste management activities required for some waste types.

**DATA REQUIREMENTS FOR MODELING WASTE MANAGEMENT ACTIVITIES WITH THE SYSTEM COST MODEL**

**Waste Types Addressed By the System Cost Model**

The SCM estimates waste management costs as a function of the waste quantities that are being managed and the characteristics of the waste being managed. The SCM can be loaded with site-specific waste, facility, processing, and schedule information to provide a somewhat customized model of the planned waste management activities for the DOE complex. Since SCM produces waste management costs for several different waste types and subtypes, waste
and facility data can be input for each waste type and subtype being modeled. The SCM is currently capable of estimating costs for three waste types—low-level waste (LLW), mixed low-level waste (MLLW), and transuranic waste (TRUW). Low-level waste and MLLW can be broken down into three subtypes: alpha-contaminated, nonalpha-contaminated, and remote-handled. Transuranic waste can be broken down into four subtypes: mixed, nonmixed, mixed remote-handled, and nonmixed remote-handled.

Waste Data

The waste data needed for cost modeling includes both current inventories and projected generation rates over the period of interest. The SCM requires that each waste stream for a given waste type/subtype be placed into one of thirty-two waste matrix categories. These waste matrix categories are defined in DOE's Mixed Waste Treatability Group Guidance, and are consistent with the format used to compile DOE's Mixed Waste Inventory Report. The waste information is usually available in the form of volumetric quantities. However, since SCM uses both mass and volume flow rates, densities of each waste matrix category are also required so the necessary conversions can be made.

Facility Data

Existing facility information is required to support modeling efforts in order to establish the waste management capabilities that exist at a particular site and what new capabilities need to be provided (and costed). The existing facility information required includes capacities or throughputs, anticipated operating life, waste types/subtypes accepted or prohibited, known operating and maintenance costs, operating hours per year, waste processing methods, secondary wastes generated as a result of specific facility operations, and waste volume and mass changes resulting from each facility.
Treatment, Storage, and Disposal Scenario

The treatment, storage, and disposal (TSD) scenario defines where each waste management step is planned to be accomplished for each waste matrix category within a particular waste subtype. For example, some waste may be treated and disposed onsite, while some waste may be treated onsite and disposed at another DOE site (i.e., Waste Isolation Pilot Plant), and still other waste may be sent to an offsite commercial facility for treatment, with the residuals shipped back to the generating site for disposal.

Cost Curves and Modules

The SCM utilizes cost versus capacity curves developed in a series of Waste Management Facilities Cost Information (WMFCI) reports. The WMFCI breaks down treatment, storage, and disposal activities into discrete functions referred to as "modules." The SCM contains different sets of cost curves for a variety of modules. Some of the more common modules used in SCM include: waste retrieval, receiving/inspection, waste characterization, open/dump/sort, shredding/compaction, decontamination, aqueous waste processing (neutralization, precipitation, ion exchange, evaporation, carbon adsorption, distillation/extraction, etc.), incineration, grout stabilization, polymer stabilization, vitrification, oxidation, thermal desorption, storage, shallow land disposal, and engineered disposal.

Module Flow Scheme

In order to model waste management costs with the SCM, a set of modules must be identified for each waste stream to represent the desired TSD functions, based on regulatory, economic, logistical, and institutional constraints. For most waste streams, as few as 2 or 3 or as many as 10 or 12 modules may be required to represent all of the planned cradle-to-grave waste management activities. This module flow scheme information allows SCM to calculate costs from the module cost curves that are presented in the WMFCI reports.
Site Schedules

Another important category of information needed for the modeling of waste management activities is schedule data. What is the planned construction start date for a specified facility? How long is construction anticipated to last? What is the work-off period for a given quantity of waste? Does the waste need to sit in storage for any period of time between generation and treatment or between treatment and disposal? Each of these schedule-related questions, as well as many others, should be answered so modeled costs are spread across the right time frame. If any of this type of schedule data is unknown, a set of defaults within the SCM can be used.

Cost Factors and Labor Rates

The final category of data required to model waste management activities and their associated costs in the SCM is cost factors. Factored costs are those that are calculated from other costs, and not estimated independently. For example, maintenance costs are factored from equipment costs, and design costs are factored from construction costs. A default set of cost factors is available in SCM, but when site-specific data is known, it should be used. Likewise, fully burdened labor rates are required to estimate labor costs through each phase of a particular waste management activity. Different labor rates for different skill levels can be input to SCM, and these rates can be customized at the site level.

FACTORS CONTRIBUTING TO UNCERTAINTY IN MODELED WASTE MANAGEMENT COST ESTIMATES

Data Limitations

Because the SCM relies on waste loads as the basis for all costs, any uncertainties in the waste data are passed directly into the cost estimates. Generally, waste inventory data is more established than waste generation projections. However, even data on the current waste inventory is limited because there is still a lot of uncharacterized and unknown waste at several
DOE sites. The Federal Facilities Compliance Act required DOE sites to gain a better understanding of their mixed waste inventories, and the information needed for modeling and cost estimating is generally available for mixed waste in the form of the Mixed Waste Inventory Report. However, nonmixed LLW and TRUW data have not been developed and kept current at the same level of detail. Consequently, different sources yield different waste loads, and this contributes significantly to modeling and cost estimating uncertainties.

Some waste generation projections are based on the continued operation of current facilities with known waste output rates; however, most projections are based solely on educated guesses (by knowledgeable site personnel) about proposed or hypothesized future activities and processes. This is a primary source of variability, since site plans change often and no real sound basis exists for future waste generation rates.

Differences in Site-Level Assumptions

Recently, DOE has made an effort to involve the state and local stakeholders in developing waste management plans. This has resulted in site-specific solutions to some of the waste problems. In some cases, negotiated agreements at one site may be built around a different level of compliance than those reached at another site. Both approaches may be perfectly valid; however, these differences in plans can be difficult to address from a modeling standpoint. Although models like the SCM are capable of being customized at the site level, some more generic assumptions are usually applied to simplify the analytical process.

Difficulty in Estimating Support Costs

One of the biggest challenges in modeling DOE's waste management costs is in estimating support costs. The DOE Waste Management Program (EM-30) budget includes costs for activities other than waste treatment, storage, and disposal. Some of these other categories of waste management costs include waste minimization programs, stakeholder involvement programs, environmental monitoring, oversight, program management, etc. Collectively, these
activities make up what is referred to as support costs. These can be a significant portion (40–60%) of a site's waste management budget. Estimating and modeling these costs is difficult because some of these costs are buried in facility operations costs, while others may be shared across several facilities, programs, or waste types, and still others may be paid for by overhead accounts. Furthermore, some support costs are fixed—they remain constant over time—and others are variable, usually a function of time, site budget, site mission, total waste processed, or some other factor that is difficult to predict. For all of these reasons, support costs contribute significantly to the uncertainty of life-cycle waste management cost estimates.

Another related factor that influences estimating waste management costs with the SCM is the fact that some site out-year estimates are not activity-based, or at least not dependent upon waste throughputs. Some DOE waste management facilities cost about the same whether they process 1,000 or 10,000 cubic meters of waste a year. In other words, these facility costs are head-count based rather than activity-based. This situation is difficult to model with the SCM, since the SCM was designed to calculate cost as a function of waste quantities processed.

### Varying Levels of Integration Between EM-30, -40, -50, and -60 Programs

Another inconsistency between sites that impacts the accuracy of modeling and cost estimating is the level to which the various EM programs (30, 40, 50, and 60) have been integrated. Some sites have developed integrated baselines. That means that common or shared facilities have been considered and both EM-40 and EM-60 have identified waste types and quantities that they will generate and turn over to EM-30 for treatment or disposal. Integration also means EM-60 has worked out a schedule of when it will turn facilities over to EM-40 for decommissioning.

Many of the DOE sites have not fully integrated their baseline plans. Consequently, there may be gaps or overlaps between the plans of the EM programs. Due to these potential problems, a high level of uncertainty exists for any sites that have not developed a fully integrated baseline.
Some Processes Use Unproven or Undeveloped Technologies

In order to establish out-year baselines, the sites have been forced to plan the types of waste management activities that they anticipate will be necessary to treat and dispose of known and projected quantities and types of waste. In some cases, sites may be planning on using technologies or processes that have not yet been proven on a production scale. For these types of plans, cost estimates are very speculative. Where there is no cost history or basis for modeling to use, uncertainties are extremely high. Along with the cost uncertainties, these unproven processes also contribute to schedule and performance issues.

Difficult to Estimate Impacts from Cost Savings Programs

In estimating the life-cycle waste management costs, DOE has tried to identify potential impacts from various cost savings programs. Among these are waste minimization, technology development, and productivity initiatives. Impacts from these types of programs are very difficult to quantify, and usually are based solely on assumptions. Consequently, cost savings programs also contribute to uncertainty in the final estimates, especially after cost to implement is considered.

External Factors—Changing Regulations, Political Environment, Stakeholders

Finally, and perhaps most significantly, there are several outside influences that create large uncertainties in life-cycle waste management cost estimates. These include impacts to planned waste management activities resulting from institutional, political, and regulatory forces. These types of influences are virtually unpredictable. Once again, in order to quantify any cost impacts from these external forces requires a set of assumptions to be applied over the life cycle of the program.
SUMMARY

Importance of Estimating DOE's Life-Cycle Waste Management Costs

The ability to estimate life-cycle waste management costs is very important to DOE. Cost information can be used to support strategic planning and policy/decision making activities. Life-cycle costs need to be evaluated as one of the key parameters used to prioritize projects and compare alternatives. Because of all of the uncertainties associated with the out-year cost estimating basis, it is not critical that DOE be able to nail down the exact costs for future waste management activities. However, it is very important that DOE apply a valid, consistent cost estimating methodology that considers the major variables. In doing this, DOE can use the resulting life-cycle cost information to help assess the potential financial implications of its decisions.

Recommendations for Improving Life-Cycle Waste Management Cost Estimates

In order to estimate life-cycle waste management costs, DOE needs to establish a baseline set of planning assumptions and apply a consistent methodology for quantifying out-year costs. The SCM has been developed to provide a cost estimating basis for typical waste management activities, and it can be customized to reflect site-specific differences. However, in order to estimate out-year waste management costs, the DOE sites must develop a data set that can be used as the basis for estimates developed with or without the SCM. Since all of the data needed for cost analysis is not readily available, it must be developed based on the sites' baseline plans. More uncertainty is introduced into cost analysis as the planning horizon is stretched out to encompass the life-cycle of waste management activities at the DOE sites. Although this uncertainty cannot be eliminated, there are some areas where future efforts can be focused to try to keep it to a minimum:

- A more comprehensive set of waste data needs to be developed for the DOE complex. Specific attention needs to be placed on out-year projections for both
mixed and nonmixed wastes and any current inventory of nonmixed waste. For cost estimating purposes, the type of data needed includes waste volumes and waste matrix categories.

- A work breakdown structure that is generally applicable for all waste management costs and detailed enough to provide specific categories for all support costs needs to be assigned. All sites' waste management costs should be developed in a format consistent with this EM-30 work breakdown structure.

- Cost savings from programs like waste minimization and technology development should not be arbitrarily applied to baseline estimates. If there is a sound basis for a particular cost avoidance or reduction, and a quantified savings can be attributed to a specific activity, then it should be included. This also applies to productivity initiatives.

- A large uncertainty is introduced to life-cycle estimates by external factors (changing regulations, politics, institutional issues, stakeholder priorities, etc.). These factors can be minimized by involving the appropriate stakeholder groups in the baseline planning process.

Conclusion

The DOE has now developed a life-cycle baseline for its EM Program. In formulating this total program estimate, DOE and the various sites have had to put some thought into what future activities will be necessary to clean up the complex. In order to establish the basis and variability of waste management costs, information about these future activities has been assembled and used in models that provide life-cycle cost estimates. To date, the information needed for modeling waste management activities has come from several sources, and carries a high level of uncertainty. The DOE's life-cycle waste management cost estimates can be improved if the uncertainties associated with the site data can be decreased. EM-30 has taken a
step in this direction by instituting a data call as part of the 1996 BEMR development process. Further improvements in modeling and cost estimating of waste management activities can be expected as the sites firm up their out-year planning basis.

REFERENCES


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