Development of Tools for Evaluating Integrated Municipal Waste Management Using Life-Cycle Management

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Abstract: Municipal solid waste (MSW) management increasingly is based on integrated systems. Traditional evaluations have focused on individual processes and not the combination of processes. Communities, planners, and policy makers are struggling to make decisions regarding how to best manage MSW without the tools and information that would help them evaluate the alternatives. The U.S. initiated research in 1994 through funding by the U.S. Environmental Protection Agency and the U.S. Department of Energy to develop (1) a decision support tool; (2) a database; and (3) case studies. This research is to be completed by the spring of 2000. A recent peer review of the technical work was conducted in the fall of 1997, and a final peer review is planned for the fall of 1999. This paper provides an overview of the research that is in process. This research is being conducted by the Research Triangle Institute, North Carolina State University, University of Wisconsin, Franklin Associates, Ltd., and Roy F. Weston, Inc. through a cooperative agreement with EPA's Office of Research and Development (ORD).

Introduction

In 1993, in response to requests from state and local governments, the U.S. Environmental Protection Agency (US EPA) and the U.S. Department of Energy (US DOE) joined forces to develop the tools and information needed to evaluate strategies for integrated waste management. These tools will allow solid waste managers to evaluate the tradeoffs between environmental emissions, energy, and costs for different integrated waste strategies for municipal solid waste processes including collection, transportation, material recovery facilities, composting, combustion, and landfilling. State and local governments are under increasing pressure to modify current programs and adopt more efficient integrated waste management strategies that reflect dynamic shifts in recycling markets and waste management goals. The US EPA has conducted this research in an inclusive process using stakeholders with representatives from state and local governments, industry, trade associations, academia, and environmental interest groups. All interim and final work products are being reviewed by an internal advisory group, stakeholders, life cycle and solid waste experts, and a formal peer review process. A peer review conducted in September 1997 concluded that the technical work conducted to date is sound and that the results from this effort could revolutionize how waste management plans are developed in the future. This review also provided a number of constructive suggestions for improving the methodology.

A series of journal articles are being developed that describe the modeling of the different processes and the technical work conducted to develop data and information for inputs to the models. The processes being modeled include collection, transfer stations, transportation, electrical energy, materials recovery facilities, combustion, composting (yard and mixed waste), refuse-derived fuel, anaerobic digestion, landfilling, and manufacturing of products from virgin and/or recovered materials. Our emphasis has been on data collection particularly for those processes where there is limited information for us to evaluate the life-cycle emissions and energy such as landfills and mixed-waste composting. We hope to complete the development of the prototype of the decision support tool (DST) by the summer of 1998. Case studies will be conducted once we have the working prototype, and we will be working with several communities in the U.S. We are also planning a project with Italy's National Agency for Environmental Protection. Each case study will be documented, and the results will be used to help illustrate how the DST can be used for answering various questions that are facing local government. The final peer review is scheduled for the fall of 1999 after the draft final reports and beta versions of the DST and database are completed. Based on the findings of the peer review, the DST will be revised and the database updated prior to release of any final outputs that are scheduled for release by the spring of 2000.

We have developed a web site for project documents and updates. The web site address is http://www.epa.gov/docs/crb/apb/apb.htm. We are updating the web site as needed as new documents and updates are available. Further questions and updates on this research should be forwarded to the EPA project officer at Thorneloe.Susan@epa.gov.

Why Use Life-Cycle Management When Modeling Integrated Waste Processes?

The life cycle of MSW starts with the production of consumer goods from virgin and/or recovered materials. Eventually, these products are discarded to the MSW stream and may be managed through a variety of options such as materials recovery, combustion, composting, and landfilling. Those materials that are recovered and recycled will be incorporated into new products and eventually will reenter the MSW stream. Life-cycle assessment provides an approach to considering the different environmental emissions and resources required for different strategies. The differences in needs between rural and urban areas as well as differing concerns regarding air and water quality can influence the types of strategies that are selected. In the past, communities have had to meet recycling or landfill diversion targets without a means to consider site-specific issues. The outputs from this research will provide the mechanism for communities to develop more efficient integrated solid waste management plans and enable decision-makers to consider factors other than cost. The scope of this project is different from the traditional life-cycle study for a specific product. A product life-cycle study focuses on the environmental effects of a given product system from cradle to grave, whereas this study focuses on minimizing the environmental burdens of the management of a ton of municipal solid waste (MSW). (White, 1995)

Life-Cycle Inventory and Cost Analysis Methodology Development

For each of the major system components, we are developing methodologies for life cycle inventory (LCI) analysis using recent guidance (e.g., Keoleian and Menerey, 1993; SETAC, 1991; Vigon et al., 1993). LCI methods are needed to allocate energy consumption and environmental

releases to individual components of the waste stream. This enables the evaluation of the environmental implications of managing individual waste components in alternative management strategies. For example, in management strategies where some portion of MSW is recovered, the recovered material will ultimately be delivered to a facility for processing into a new consumer good. Separation will occur during collection, at a materials recovery facility (MRF), or at another waste management facility. Energy and resources will be expended to deliver the recovered material to a processing facility. At this facility, additional energy and resources will be expended to convert the recovered material to a new product. The total amount of energy required to recover the material from the waste stream and convert it to a new product will be included in the inventory analysis. In addition, the amount of energy required to produce a similar amount of product from virgin resources is included. The net amount of energy expended (or saved) to recycle a material will then be calculated as the difference between generating consumer goods from recovered materials versus generating them from mostly virgin resources. A similar analysis is also being done for environmental releases (air, water, and solid waste).

For cost analysis, we are developing methodologies for operations that represent costs or revenues to municipalities. Thus, the cost analysis will include all waste management operations and any revenues generated through the sale of recovered materials or fuels.

The LCI and cost methodologies are implemented in process models. These models include sets of equations that utilize the default (or user input) facility design information for individual unit operations to calculate all LCI and cost parameters for each individual waste management operation. LCI and cost parameters are calculated in the process models based on the quantity and composition of waste entering each operation and thus are intricately linked to the system waste flow equations. Process models are being developed for all waste management operations included in the system components.

System Components

The system components for this research include the following major unit operations:

Manufacturing of Products from Virgin and Recycled Materials
Collection
Transfer Station
Inter-Unit Operation Transportation (including rail haul)
Materials Recovery Facility
Combustion (with and without energy recovery)
Composting (mixed MSW and yard waste)
Refuse-Derived Fuel (RDF)
Anaerobic Digestion
Landfill (both with and without gas and leachate control; and operated as an enhanced bioreactor)

All system components are linked together through a series of materials flow equations. These equations determine the quantity and composition of materials flow to and from each unit

operation in the system. Most of the above process modules are complete except for those where additional work is ongoing to complete data gaps (i.e., anaerobic digestion, compost facilities, landfills, and RDF).

Data Collection

A large component of this research effort is collecting consistent environmental and cost data across all unit operations so they can be compared directly. Currently, such data do not exist. For example, although detailed data on air emissions are abundant for municipal waste combustion, relatively little data on air emissions exist for collection, MRF, compost, and landfill operations.

Data for waste management operations are being compiled at two levels. First, all existing data are compiled for individual waste management operations, and major gaps and deficiencies are identified. Second, where major gaps or deficiencies exist, data are collected through contacts with state and local governments, industry experts, and academia, and through laboratory or field measurement and analysis.

Research being conducted by the University of Wisconsin at Madison is providing the data and information needed for modeling mixed and yard waste composting operations on a waste component basis (e.g., paper, food, yard, mixed waste). Another extensive effort by the Environmental Industry Associations' Research and Education Foundation will collect data for modern sanitary landfills. Other data are being obtained from primary sources in the U.S. and Europe. This effort is resulting in one of the most complete efforts to date on the life-cycle emissions associated with landfilling municipal waste.

In addition, data are also being collected to provide an understanding of the difference in emissions between products generated using "virgin" resources versus recovered materials. These data are complete for aluminum, glass containers, old corrugated containers, and old newsprint (ONP). Plastic resins, steel, office paper, and updates to ONP and aluminum ingots will be completed in the next 6 months. This has been a tremendous challenge because there are not publicly available life-cycle data for North America like there are for Europe. All information being used will undergo several layers of review including that by our stakeholders and external peer reviewers.

Main Research Products

The overall goal of this research is to develop information and tools that enable local governments and solid waste planners to evaluate the environmental performance and cost of managing MSW. The primary outputs of this research will include a database, decision support tool, and case studies. Each of these outputs is described in the following sections.

Computer Database Containing LCI and Cost Data

LCI data for individual waste management operations and upstream manufacturing operations are being developed, including equipment requirements, energy requirements, material and byproduct throughput, and environmental releases. Cost data cover typical capital and operating costs borne by local governments based on the waste management system design. These data are also included in a stand-alone database. The database allows users to search for data specific to a system unit operation, structure, or piece of equipment and an LCI or cost parameter. A beta version is scheduled for completion in the fall of 1998, and a final version is scheduled for completion in the fall of 1999.

Computer-Based Decision Support Tool

The decision support tool being developed through this research integrates default data from the database, system materials flow equations, LCI and cost methodologies, and an optimization routine in a user-friendly interface. This tool is being designed to allow MSW planners to enter site-specific data (or rely on the default data) to compare alternative MSW management strategies for their communities' waste quantity and composition and other constraints. A prototype version is anticipated in the spring of 1998 and a beta version in the spring of 1999.

Community Case Studies

Case studies are to be conducted to test the LCI and cost methodologies and the overall decision support tool. Initial case studies will take place in the spring of 1998 and are designed to test the methodologies developed for individual operations (e.g., waste collection, transportation, and MRFs). Future case studies will test the prototype decision support tool. Case study sites will include both urban and rural settings throughout the U.S. to ensure that the decision support system is flexible enough to handle the wide range of variation among local communities. In addition, discussions are ongoing in Italy and the United Kingdom to conduct additional case studies.

Research Team

The research team for this project includes life cycle and solid waste management experts from Research Triangle Institute, North Carolina State University, the University of Wisconsin-Madison, Franklin Associates, and Roy F. Weston, Inc. The landfill life-cycle project -- which focuses on state-of-the-art facilities -- is being conducted by Ecobalance with funding from U.S. and French solid waste management industries through the Environmental Industry Associations' Research and Education Foundation. In addition, groups of EPA and DOE advisors and stakeholders from industry, state and local governments, academia, and environmental advocacy organizations are active participants in this unique forum.

Summary

The next major event for this research is the peer review scheduled for the fall of 1999 before any outputs are formally released. Current efforts are focused on completing the DST, data collection, and beginning the case studies in the summer of 1998. We welcome input into this research and applaud the efforts of others working towards providing a more scientifically based approach for evaluating the different strategies for integrated waste management.

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16. ABSTRACT The paper gives an overview of U. S. in-process municipal solid waste (MSW) management research initiated in 1994 through funding by the U. S. EPA and the U. S. Department of Energy to develop (1) a decision support tool; (2) a database; and (3) case studies. This research is being done by Research Triangle Institute, North Carolina State University, the University of Wisconsin, Franklin Associates, Ltd., and Roy F. Weston, Inc. through a cooperative agreement with EPA's Office of Research and Development. MSW management increasingly is based on integrated systems. Traditional evaluations have focused on individual processes and not the combination of processes. Communities, planners, and policy makers are struggling to make decisions regarding how to best manage MSW without the tools and information that would help them evaluate the alternatives.

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Wastes	Stationary Sources	14G
Waste Treatment	Municipal Waste Management	05A
Management		
Evaluation		06P
Life-Cycles		

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