Towards Sustainable Waste Management Using a Life-cycle Management Decision Support Tool

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Abstract

Local governments have the primary responsibility for the collection, treatment, and disposal of municipal solid waste. In developing sustainable strategies for solid waste management, communities seek approaches that are economically viable and beneficial to the environment and quality of life. Although communities have had access to reliable cost information related to their MSW management systems, they have lacked comparable environmental information with which to assess the environmental benefits and burdens of alternative MSW management options. Many communities, planners, and policy-makers are often faced with limited and unorganized information on which to base decisions regarding integrated MSW management strategies. A computer-based decision support tool has been developed through a partnership of the U.S. Environmental Protection Agency and the Research Triangle Institute and its research partners. The tool has been designed to assist local governments in evaluating the cost and environmental performance of integrated MSW management systems. Ongoing case studies of the tool at the local level are summarized. The tool is also being evaluated for application at state and national levels through case studies. One state-level case study is summarized to illustrate how the decision support tool was used to estimate the environmental benefits of the state's recycling program over time.

Introduction

Local governments have the primary responsibility for the collection, treatment, and disposal of municipal solid waste (MSW). Efficient use of manpower, equipment, materials, and energy is one of the keys to building a sustainable MSW management system. Another key is making the system economically feasible over the long term.

In developing sustainable strategies for MSW management, communities seek approaches that are economically viable and beneficial to the environment and quality of life. Although communities have had access to reliable cost information related to their MSW management systems, they have lacked comparable environmental information with which to assess the environmental benefits and burdens of alternative MSW management options. Many communities and solid waste planners are often faced with limited and unorganized information on which to base decisions regarding integrated MSW management strategies.

The U.S. Environmental Protection Agency's (U.S. EPA's) Office of Research and Development is working with the Research Triangle Institute (RTI) and its partners to develop a computer-based decision support tool designed to evaluate the cost and environmental performance of integrated MSW management systems. By adopting MSW management strategies that improve the integration and efficiency of MSW management operations, local governments can help reduce the release of greenhouse gases, conserve energy and other natural resources, reduce impacts to local air and water quality or ecosystems, and improve the quality of life in their communities.

In addition to the decision support tool, this research is producing a stand-alone database that enables users to search for data specific to a waste management system unit operation, structure, piece of equipment, or life-cycle inventory (LCI) parameter (air emission, waterborne effluent, solid waste). The information and tools developed through this effort will enable the evaluation of the tradeoffs among environmental burdens, energy, and costs for different integrated waste strategies for MSW management including collection, separation, transportation, material recovery facilities, remanufacturing, composting, combustion, and landfilling.

Decision Support Tool

The decision support tool is a screening-level tool designed to aid in evaluating the cost and environmental burdens of integrated MSW management strategies. It enables users to simulate existing MSW management strategies and conduct scenario analyses of new strategies to optimize the cost or environmental performance of the system. The tool is designed to be used in conjunction with community-specific data such as waste generation and composition, recycling or diversion programs, and facility (e.g., landfill) design and operation.

The processes that can be modeled using the tool include multiple alternatives for waste collection, transfer stations, materials recovery facilities, mixed municipal and yard waste composting, combustion, refuse-derived fuel combustion, and disposal in a traditional, bioreactor, or ash landfill. Existing facilities and equipment can be incorporated as constraints to ensure that previous capital expenditures are not negated. A screen capture of summary-level results from the tool is shown in Figure 1.

In addition to viewing summary-level results, users can click down to obtain more detail about each waste management operation selected. Data on all environmental burdens that include multi-pollutants and media are available on a total or process level basis. This information can be used to help evaluate the tradeoffs of different strategies and evaluate environmental performance. In addition, the full costs associated with the management of integrated waste management systems are also provided for the total strategy or on a process level basis.

Communities and solid waste planners can use the tool, for example, to evaluate the effects of changes in the existing MSW management on cost; identify least-cost ways to manage recycling and waste diversion; and evaluate options for reducing greenhouse gases, criteria pollutants, and environmental burdens to water quality or ecosystems. The tool will also be valuable to other user groups, including military bases, environmental and solid waste consultants, industry, life-cycle practitioners, and environmental advocacy organizations in responding to the following example issues:

- changes in waste diversion, or recycling goals,
- changes in market value for recovered materials,
- quantifying potential environmental benefits associated with recycling, and
- identifying strategies for optimizing energy recovery from MSW.

Through ongoing case studies, the potential applications of the tool will be evaluated to help clearly understand the potential uses and limitations of the tool and information. The decision support tool contains general engineering cost parameters, and therefore is not intended for setting prices for any specific waste management service. The cost results provided by the tool represent screening-level engineering costs that accrue to the public entity (i.e., local government). A more detailed cash flow analysis substituting local parameters would be needed to determine the appropriate prices for services and materials. The tool is also not designed to conduct life-cycle comparisons of any specific products or materials. It is considered to be a comprehensive tool of significant value in finding improved solutions for sustainable waste management.

Testing of the Tool in Community-Based Case Studies

A prototype of the decision support tool is being tested in a number of case study applications. Case studies are ongoing with Lucas County, Ohio; the Great River Regional Waste Authority, Iowa; Anderson County, South Carolina; the State of Wisconsin; the Integrated Waste Services Association; and the U.S. Navy. Although the tool was originally designed with local communities in mind, we are testing it in applications at the state and national levels as well. Examples of the types of issues being analyzed with the decision support tool for different groups and studies are:

- Lucas County, Ohio, is currently developing a 15-year plan for their solid waste management system. They feel their current waste operations are not cost effective and ignore pollution and life-cycle implications. The analyses and results of this case study are helping in the development of integrated, cost-effective, and environmentally preferable plans and targeting opportunities for increasing recycling rates, reducing costs, and improving environmental performance.

- The Great River Regional Waste Authority in Iowa is exploring the efficiency of integrated collection system versus multiple collection options. Their goal is to evaluate effects of reconfiguring service areas and applying existing systems to them, and to develop a waste management plan for a 50% recycling scenario that is to be presented to the state authority.

- Anderson County, South Carolina, is evaluating the cost and environmental implications of implementing a residential curbside recycling program for the more densely populated areas of the County as well as setting up a yard waste composting program. The results of this study will assist the County in determining the most cost-effective strategies for implementing the programs while simultaneously considering environmental performance.

- The State of Georgia used the tool to analyze the effects of a yard waste ban on air emissions for Gwinnett County. Current nitrogen oxide (NO_x) emissions attributable to yard waste collection were estimated to be 105 tons per year, and the elimination of a yard waste ban would result in an 11% decrease in NO_x. The number of trucks needed for collecting commingled yard waste with MSW increases from 171 (with no yard waste collected with MSW) to 201. Discussions are underway to conduct additional case studies in Georgia in evaluating regional solutions to integrated waste management.

- The State of Wisconsin is investigating the environmental benefits of statewide recycling programs. We are using the tool to analyze how changes in levels of state-mandated recycling goals can potentially affect environmental burdens. The results of this study will assist the State in deciding what solid waste strategies should be used in the future to meet environmental improvement goals.

- The Integrated Waste Services Association is interested in analyzing the effect that advancements in MSW management technologies have on greenhouse gas emissions. We are using the tool to investigate the greenhouse gas emissions from various technologies including landfill gas recovery, waste-to-energy combustion, and recycling.

- The U.S Navy has requested a case study for the Navy Region Northwest. There is major interest to reduce cost, increase recycling rates, and ensure that environmental goals are being met. In addition, with the closing of smaller local landfills and transporting waste by rail to a larger regional site, the Navy is interested in evaluating the change in environmental burdens, energy, and economics. The Navy is also evaluating options that would combine waste from nearby communities to identify more cost effective and environmentally preferable solutions to a more regional approach for integrated waste management. The case study is to be conducted by the fall of 2000 and will result in implementation of a solid waste management plan. The Navy is also considering additional case studies in San Diego and the Pacific Rim.

These case studies are providing cost and environmental information about alternative waste management strategies to these groups to assist in the development of management plans and policies. The case studies also are enabling the research team refine the methods and data used in the decision support tool as well as the user interface to the tool. For illustrative purposes, the details for one of these studies (State of Wisconsin) appear in the following section. However, the findings are considered preliminary, not final. Once comments are received from the State of Wisconsin, and the tool and associated data have received final clearance, we will then be able to release findings from U.S. case studies.

Additional case studies are planned and will reflect the issues of urban and rural settings throughout the United States to ensure that the decision support system is flexible enough to handle the wide range of variation among local communities.

Wisconsin Case Study Methodology and Results

The purpose of the State of Wisconsin case study was to use the decision support tool to estimate the environmental effects of recycling and waste management in Wisconsin. In this study, the full life-cycle benefits (or burdens) of additional recycling being done in Wisconsin in 2000 as compared to 1995 were quantified. A life-cycle approach was taken to estimate the air, water, and solid waste releases, and the energy consumed for managing Wisconsin's waste in 1995 and 2000. This approach includes the stages of waste collection, processing, treatment, and disposal and materials recycling and reprocessing. This section presents a summary of the methods, results, and findings of the case study for purposes of illustration.

Waste Composition, Generation, and Recycling Data

A case study methodology document was prepared that describes the data sources and assumptions made in entering the waste composition, generation, and recycling data for the State of Wisconsin for the model years 1995 and 2000. Waste generation and recycling rates, as shown in Table 1, were estimated for the years 2000 and 1995 based on information collected in the state.

Collection, Recycling, and Disposal Options for Residential, Multifamily, and Commercial Waste

In establishing a model scenario for year 2000 and year 1995 for the entire State of Wisconsin, a general strategy of waste management was defined. This strategy was used as the basis for calculating results and includes:

- Collection of presorted recyclables and remaining (residual) mixed waste.
- Processing of recyclables in a presorted materials recovery facility.
- Disposal of residual waste in a Subtitle D landfill.
- Composting of yardwaste in a yardwaste composting facility (note that, in addition to yardwaste sent to the compost facility, yardwaste is also composted in residential backyards).

Key Assumptions Employed

When applying the decision support tool to the real-world waste management practices of Wisconsin, some assumptions are required to "fit" the real-world practices into the modeling environment of the tool. For example, a community may track a waste material that is not included in the tool (e.g., pallets, household hazardous waste) and thus an assumption must be made as how best to handle such material.

Some of the key assumptions employed in the Wisconsin case study include:

- Some materials that were recycled in Wisconsin could not be treated as such in the tool because it does not contain remanufacturing data for those items (e.g., food waste, batteries, tires). These items were excluded from the waste generation numbers for purposes of the case study and represent approximately 5% of waste generated. This assumption decreases the total amount of material recycled, and ignores the downstream LCI benefits (or costs) of recycling the materials. The materials that were excluded from the analysis are listed in Table 2.

- The LCI for composting of 290,000 tons of yardwaste composted in residential backyards was added to the LCI of yardwaste that was collected and treated at a composting facility for each model year.

Discussion of Results

The results from the analysis of recycling in Wisconsin in 1995 versus 2000 are presented in Table 3. From these results, the following points were made:

- The recycling levels for model year 2000 were higher than those for model year 1995, for all waste components. The net emissions include emissions from the collection, processing, treatment, disposal, and remanufacturing of waste and recyclables in Wisconsin.
- For several air emission parameters and for energy consumption, the net numbers are negative. The negative number indicates that there was a net savings or offset in emissions for those LCI parameters due to the environmental benefits of recycling.
- The results show that recycling at year 2000 levels results in lower LCI parameter values for some parameters, and higher values for others.
- The higher net values of LCI parameters in 2000 can be explained by the increased quantities of waste generated, collected, recycled, and disposed of in 2000 over 1995 levels. For example, in year 2000, there was a 4% increase in the quantity of waste landfilled over 1995 levels. There was a corresponding 11% increase in net methane releases for year 2000. This increase in methane emissions can be partly explained by the higher quantity of waste landfilled (that generates methane during decomposition) in year 2000.
- For some air emissions, recycling at year 2000 levels resulted in lower emissions compared to year 1995 (which had lower recycling levels). The lower numbers for model year 2000 are due to the environmental benefits of recycling.
- Emissions and energy use in the remanufacturing of recyclables recovered from waste dominate emissions and energy use in the waste collection, processing, treatment, and disposal stages of waste management.

Project Information

When completed, the decision support tool and LCI database will be publicly available. RTI is working to develop an agreement to determine how the outputs will be formally released. The EPA is planning to develop a Cooperative Research and Development Agreement (CRADA) with the commercial partner or partners that will address future updates, maintenance, technical support, and other issues associated with the release and application of the decision support tool and LCI database.

Major emphasis will be towards ensuring that the cost of the tool is kept to a minimum to provide wide access. The fee for the release of the tools will help to cover the costs associated with future updates, maintenance, and technical support that stakeholders have stated are essential in ensuring the success of this tool.

Those who are interested in application of the tool, such as local and state governments, may want to obtain a copy for use in-house or to contract the services of consultants. The tool and supporting documentation have been developed so that solid waste management professionals can use the tool for a wide range of applications. A user's manual and other extensive documentation will be available as well as documentation of the case studies conducted to date. The details of how the final outputs will be released will be determined over the next several months with emphasis on the needs and interests of the stakeholders.

General project information and interim draft documentation are completed and being finalized. Final reports include user's manuals for both the database and decision support tool, and a project overview report with detailed documentation of process models, data, and methodology. Final reports and documentation are scheduled to be released this summer. Available information can be found on the project Internet site (www.rti.org/units/esc/p2/lca.cfm#life), including a PowerPoint presentation of the decision support tool. The research team is also preparing a series of peer-reviewed journal articles to highlight the different aspects and uses of this tool and to summarize findings from case studies in different communities where this life-cycle tool has been applied.

Acknowledgments

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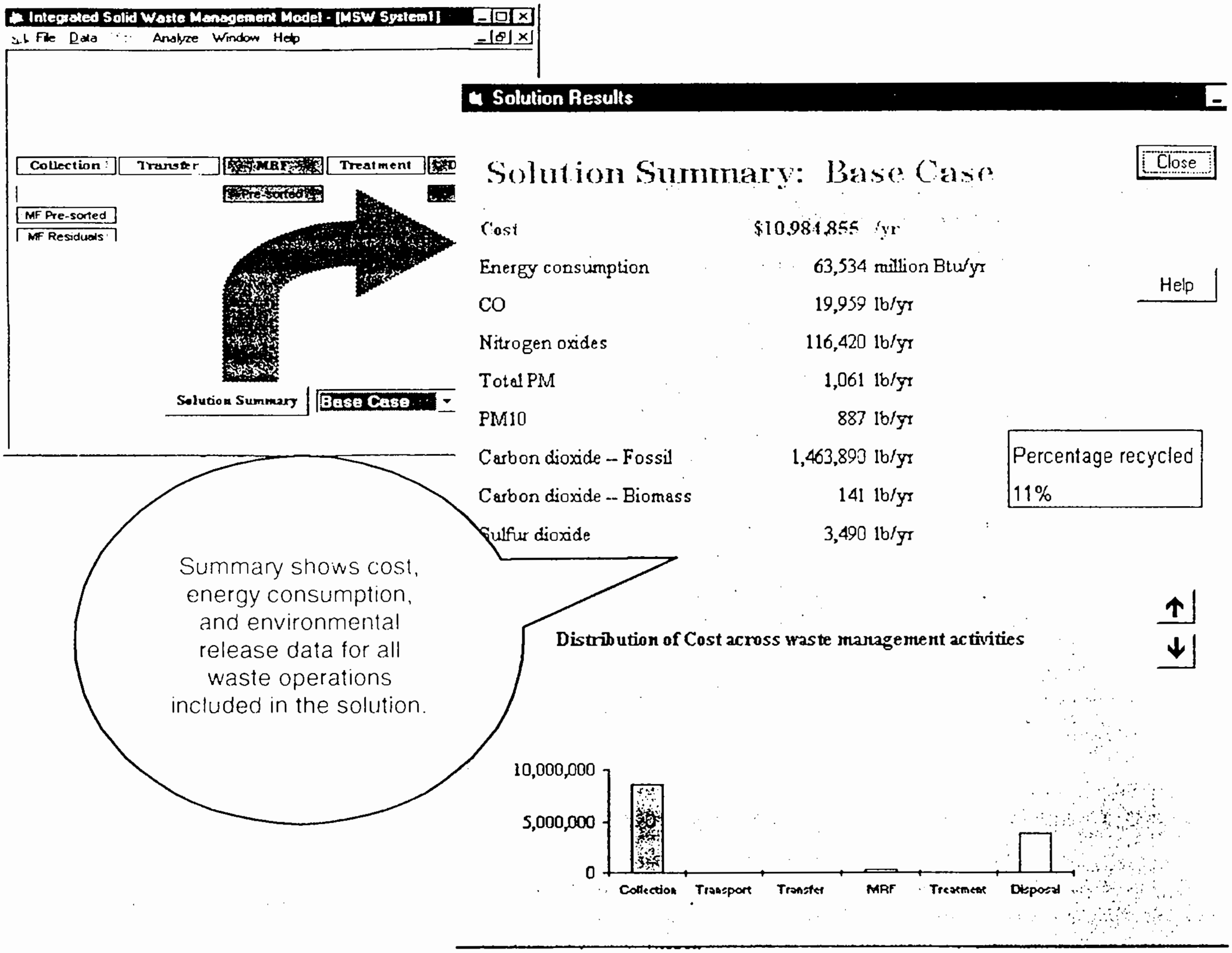

Note: The number of significant digits shown in the decision support tool results is currently being adjusted. The final version of the tool will display 2-3 significant digits.

Figure 1. Solution Summary.

The user can view the suggested cost and environmental data for the suggested waste management strategy. In addition, the user can view process-level data on the full costs and life-cycle environmental burdens.

Table 1. Summary of Waste Flows Modeled for the State of Wisconsin.

Waste Generation by Category (data used to generate results)	2000 (projected) (tons)	1995 (tons)	Change in 2000 from 1995 levels (%)
Waste Generated			
Residential	1,880,000	1,860,000	1
Multifamily	220,000	213,000	3
Commercial	1,600,000	1,440,000	11
Materials recycled in Wisconsin that are not captured in model	220,000	201,000	10
total	3,920,000	3,720,000	6
Materials Recycled			
Residential	353,000	349,000	1
Multifamily	36,900	35,800	3
Commercial	617,000	557,000	11
Materials recycled in Wisconsin that are not captured in model	220,000	201,000	10
total	1,230,000	1,140,000	7
Yardwaste Diverted from Landfill			
Backyard Composting	290,000	290,000	0
Yardwaste Composting at Facility	200,000	199,000	1
total	490,000	489,000	0
Waste Landfilled			
Residential	1,330,000	1,310,000	1
Multifamily	183,000	177,000	3
Commercial	982,000	886,000	11
total	2,490,000	2,370,000	5

Notes:

- These data are outputs from the decision support tool to generate the life-cycle profile for waste management in Wisconsin.
- The recycled quantities are slightly different from actual numbers expected using Wisconsin data due to rounding and the assumptions made.

Table 2. Materials Recycled in the State of Wisconsin But Not Captured By This Model.

Materials	2000 (projected) (tons)	1995 (tons)
foam polystyrene packaging	0	40
foam polystyrene nondurable goods	0	310
other plastic containers	9,920	8,610
other plastic packaging	300	240
food waste	14,800	13,400
vehicle batteries	41,100	36,700
tires	1,730	1,550
textiles, rubber & leather products	22,000	18,500
carpets and rugs	750	560
major appliances	69,500	69,800
miscellaneous durables	20,000	17,300
wood pallets	40,000	33,700
miscellaneous packaging	440	400
totals	**221,000**	**201,000**

Table 3. Summaries of Life-Cycle Parameters for the State of Wisconsin in 2000 and 1995

Net Decreases in LCI for year 2000 over year 1995 levels

Parameter	Units	2000 LCI	1995 LCI	Decrease in 2000 (%)
Energy Consumption	Million BTU/year	-18,400,000	-16,300,000	13
Air Emissions				
Total Particulate Matter	lbs/year	-7,100,000	-6,660,000	7
Nitrogen Oxides	lbs/year	-5,700,000	-4,110,000	39
Sulfur Oxides	lbs/year	-28,300,000	-26,200,000	8
Carbon Monoxide	lbs/year	-58,900,000	-53,400,000	10
Carbon Dioxide (Biomass sources)	lbs/year	-4,810,000,000	-4,250,000,000	13
Hydrocarbons (non-CH4)	lbs/year	-2,180,000	-2,070,000	5
Lead	lbs/year	-172,000	-156,000	10
Ammonia	lbs/year	-3,160	-2,800	11
Total Solid Waste	lbs/year	-260,000,000	-258,000,000	1
Water Releases				
COD	lbs/year	-14,000,000	-12,500,000	12
Sulfuric Acid	lbs/year	-317,000	-272,000	17
Ammonia	lbs/year	-59,000	-52,000	13

Net Increases in LCI for year 2000 over year 1995 levels

Parameter	Units	2000 LCI	1995 LCI	Increase in 2000 (%)
Air Emissions				
Carbon Dioxide (Fossil sources)	lbs/year	730,000,000	633,000,000	15
Carbon Equivalents	tons /year	153,000	138,000	12
Methane (CH4)	lbs/year	18,800,000	17,900,000	5
Hydrochloric Acid	lbs/year	-31,500	-38,000	17
Water Releases				
Dissolved Solids	lbs/year	4,630,000	4,450,000	4
Suspended Solids	lbs/year	-113,000	-339,000	67
BOD	lbs/year	5,740,000	5,290,000	9
Oil	lbs/year	730,000	661,000	10
Iron	lbs/year	765,000	695,000	10
Phosphate	lbs/year	17,500	16,200	8
Zinc	lbs/year	10,700	9,650	11

Note:

- These data are totals for the entire waste management system including collection, recycling, composting, disposal, and remanufacturing.
- Negative numbers indicate that there were net savings in emissions.

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16. ABSTRACT The paper discusses a computer-based decision support tool that has been developed to assist local governments in evaluating the cost and environmental performance of integrated municipal solid waste (MSW) management systems. Ongoing case studies of the tool at the local level are summarized. The tool is also being evaluated for application at state and national levels through case studies. One state-level case study is summarized to illustrate how the decision support tool was used to estimate the environmental benefits of the state's recycling program over time. (NOTE: Local governments have the primary responsibility for the collection, treatment, and disposal of MSW. In developing sustainable strategies for solid waste management, communities seek approaches that are economically viable and beneficial to the environment and quality of life. Although communities have had access to reliable cost information related to their MSW management systems, they have lacked comparable environmental information with which to assess the environmental benefits and burdens of alternative MSW management options. Many communities, planners, and policy-makers are often faced with limited and unorganized information on which to base decisions regarding integrated MSW management strategies.)

17. KEY WORDS AND DOCUMENT ANALYSIS

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Pollution		Pollution Control	13B	
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Wastes	Performance Evaluation		14G	
Management			05A	05I
Evaluation	Decision Making			05J
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