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A Decision Support Tool for Assessing the Cost and Environmental Burdens of Integrated Municipal Solid Waste Management Strategies:

USERS MANUAL

DRAFT

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Notice

This manual has been developed as part of research funded by the U.S. Environmental Protection Agency and U.S. Department of Energy through EPA Cooperative Agreement No. CR823052 with the Research Triangle Institute. The decision support tool is intended for use in evaluating the relative cost and environmental burdens of integrated municipal solid waste management strategies. The information and results from this tool are not intended for use in making comparative assertions about the environmental preferability of alternative materials or products. Use of the methods or data presented in this manual does not constitute endorsement or recommendation for use. This manual is subject to review and modification prior to conclusion of the research. Mention of trade names or commercial products does not constitute endorsement or recommendation.

Abstract

Communities throughout the United States are struggling to develop efficient and cost-effective plans for managing their municipal solid waste (MSW). Today's MSW management systems often are complex and highly integrated systems that might include separate recyclables collection, recovery, composting, combustion, and disposal. Communities now must make complex decisions requiring an analysis of both cost and environmental burdens for these integrated systems. Despite the movement toward integrated systems, many of the existing techniques for analyzing the environmental and economic performance of MSW management systems focuses on the individual operations in isolation rather than as part of an integrated system.

To properly account for all of the environmental effects associated with integrated MSW management systems, planners must have tools that allow them to examine factors outside of the traditional MSW management framework of activities occurring from the point of waste collection to final disposal. The U.S. Environmental Protection Agency's (EPA's) Office of Research and Development, Air Pollution Prevention and Control Division, with cofunding from the U.S. Department of Energy, worked with solid waste management and life cycle assessment (LCA) experts from Research Triangle Institute, North Carolina State University, the University of Wisconsin-Madison, Franklin Associates, and Roy F. Weston to develop a computer based a tool to assist solid waste practitioners in identifying integrated MSW management strategies that minimize both cost and environmental burdens.

This user's manual has been prepared to provide the reader with a general overview of the computer tool developed through this research as well as more detailed information to assist users in building scenarios for analysis. Detailed documentation about the data and methods used for each unit process included in the tool are available as separate documents.

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Abbreviations and Symbols

BTU	British Thermal Unit
U.S. DOE	United States Department of Energy
DQG	Data Quality Goal
DQI	Data Quality Indicator
DST	Decision Support Tool
EIA	Energy Information Administration
FAL	Franklin Associates, Limited
GUI	Graphical User Interface
KWH	Kilowatt Hour
LCA	Life-Cycle Assessment
LCI	Life-Cycle Inventory
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
NCSU	North Carolina State University
NERC	North American Electric Reliability Council
O&M	Operation and Maintenance
POTW	Publicly Owned Treatment Works
RCRA	Resource Conservation and Recovery Act
RDF	Refuse-Derived Fuel
RTI	Research Triangle Institute
SETAC	Society for Environmental Toxicology and Chemistry
TPD	Tons Per Day
U.S. EPA	United States Environmental Protection Agency
UW	University of Wisconsin - Madison
WTE	Waste-To-Energy Combustion

Key Terms and Definitions

Allocation: Technique for partitioning multiple inputs and outputs from a system.

Cost: Amount actually incurred for the provision of a product or service. Cost can include internal cost accrued by an organization, external costs accrued by society.

Data Quality Indicator: Measure which characterizes an attribute(s) of data or data sets.

Function: Performance characteristic of a system.

Functional Unit: Measure of performance of the main functional output of a system.

Integrated Waste Management: Interlinked stages of a system to collect, process, treat, and dispose of waste.

Life Cycle: Consecutive and interlinked stages of a system that extend from raw materials acquisition or generation of natural resources to final disposal.

Life Cycle Assessment: Compilation and evaluation, according to a systematic set of procedures, of the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the function of a product throughout its life cycle.

Life Cycle Impact Assessment: Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of environmental impacts based on a life cycle inventory analysis.

Life Cycle Inventory Analysis: Phase of life cycle assessment that involves compiling and quantifying the inputs and outputs for a given product system throughout its life cycle.

Municipal Solid Waste: Waste generated in the residential, multifamily, and commercial sectors. Includes durable goods, nondurable goods, containers and packaging, food waste, and yard trimmings. Also includes ash from waste combustion. Excludes industrial process waste, sludge, construction and demolition waste, pathological waste, agricultural waste, mining waste and hazardous waste.

Price: Amount actually charged/paid for a product or service.

Key Terms and Definitions (Cont.)

Process Model: Mathematical representation of a unit process to calculate cost and environmental burdens as a function of the quantity and composition of the waste or material processed.

Raw Material: Primary or secondary recovered or recycled material that is used in a system to produce a product.

System: Collection of unit processes which, when acting together, perform some defined function.

Unit Process: Component of the system being studied that is a collection of operations which transforms inputs into outputs, such as manufacturing, waste collection, materials recovery, etc.

Section 1

Introduction

This manual is designed to provide the user of the Decision Support Tool (DST) with the essential information required to use the tool to conduct scenario analyses of integrated municipal solid waste (MSW) management strategies. The overall focus of the DST is to support the evaluation of cost and environmental burdens associated with alternative strategies for integrated MSW management in a particular community or region.

The tool is designed to analyze the management of MSW of a given quantity and composition. It considers all activities required to manage the MSW from the time it is sent out for collection to its ultimate disposition, whether that be disposal in a landfill, compost applied to the land, energy recovered from combustion or landfills, or materials recovered and remanufactured into new products. It can help to answer questions such as how do the cost and environmental burdens associated with a MSW management system change if clear glass containers are added to or removed from a community's recycling program? Or, what are the tradeoffs in cost and environmental burdens if newspaper is recycled versus combusted or landfilled with energy recovery?

This user's manual will first answer some basic questions and, in subsequent chapters, will summarize the methodologies used in the tool and demonstrate how to use it to conduct scenario analyses of integrated MSW management options. Upon accessing the DST, you'll find the help system especially helpful. To access the help system, simply press the help button on any screen or from the menu.

1.1 WHAT ARE APPROPRIATE USES FOR THE TOOL?

The DST is a screening level tool designed for use in evaluating community level MSW management strategies. It allows you to conduct scenario analyses of strategies with the objective of optimizing cost or environmental performance of the system. The MSW management system modeled may be an existing system, entirely new systems, or some combination of both based on user-specified data on MSW generation, requirements, etc. The processes that can be modeled include waste generation, collection, transfer, separation (material recovery and drop-off facilities), composting, combustion, refuse-derived fuel, and disposal in a landfill. Existing facilities and equipment can be incorporated as model constraints to ensure that previous capital expenditures are not negated by the model solution.

The DST was designed with local governments and solid waste planners in mind as the primary users of the tool. At the local level, the tool can be used to evaluate, for example, the affects of

changes in the existing MSW management on cost and environmental burdens, identify least cost ways to manage recycling and waste diversion, evaluate options for reducing greenhouse gases or air toxics, or estimate the environmental benefit of recycling. The tool will also be of value to other user groups such as Federal agencies, environmental and solid waste consultants, industry, LCA practitioners, and environmental advocacy organizations. These users can use the tool, for example, to evaluate recycling policies and programs, policies and technologies for reducing environmental burdens, and strategies for optimizing energy recovery from MSW.

The tool is not a cash flow model and therefore should not be used to set prices for any specific waste management service. The cost results provided by the tool represent screening level engineering costs. A more detailed cash flow analysis would be needed to determine the appropriate prices for services and materials.

The tool also should not be used to conduct life cycle comparisons of specific products or materials. The LCI results for recycling are based on generic process designs for product manufacturing and remanufacturing operations. To properly compare the preferability of packaging materials, you would need to do a more in-depth analysis of the production, use, and pre-consumer recycling of the products or materials.

Future information about the appropriate uses and limitations of the DST is provided in Section 4 of this users manual.

1.2 WHAT ARE THE BASIC COMPONENTS OF THE TOOL?

As illustrated in Figure 1-1, the DST consists of four basic components: process models, waste flow model, optimization model, and a graphic user interface (GUI). The process models consist of a set of spreadsheets developed in Microsoft Excel. These spreadsheets use a combination of default and user supplied data to calculate the cost and life cycle inventory (LCI) coefficients on a per unit mass basis for each of the 48 MSW components being modeled for each solid waste management unit process (collection, transfer, etc.). For example, in the electric energy spreadsheet, the user is asked to specify the fuel mix used to generate electricity in the geographic region of interest. Based on this design information and the emissions associated with generating electricity from each fuel type, the spreadsheet calculates coefficients for emissions related to the use of a kilowatt hour of electricity. These emissions are then assigned to waste stream components for each facility that uses electricity and through which the mass flows. For example, material recovery facilities (MRFs) use electricity for conveyors and lighting. The emissions associated with electricity generation would be assigned to the mass that flowed through that facility. The user can bypass default data if more site specific data are available.

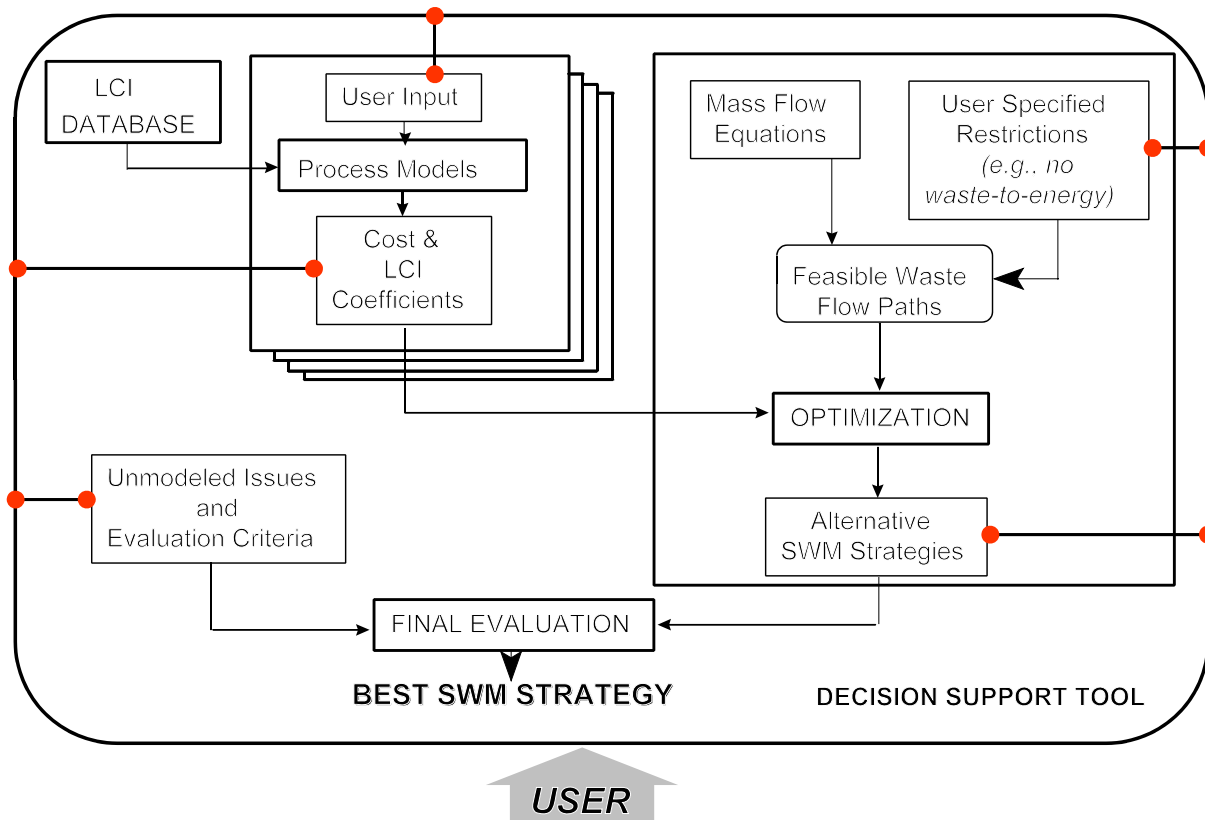


Figure 1-1. Conceptual Framework for Decision Support Tool

The waste flow model essentially provides a mass balance of the system. MSW can be collected by a variety of different collection alternatives and collection combinations and then can flow through additional alternatives for transfer, separation, treatment, and disposal. The waste flow model defines all possible pathways for the MSW. It helps to link the process models and facilitate optimization. It also helps to prevent infeasible waste flows. For example, aluminum cans would not go to a yard waste compost facility. Similarly, glass would not be collected and sent to a MRF if the MRF doesn't have a glass crusher. The waste flow model communicates with the optimization module to search for optimal solutions from the large number of possible MSW management strategies.

The optimization module is implemented using the CPLEX linear programming solver. The model is constrained by mass flow equations that are based on the quantity and composition of waste entering each unit process, and that intricately link the different unit processes in the waste management system (i.e., collection, recycling, treatment, and disposal options). These mass flow constraints preclude impossible or nonsensical model solutions. For example, these mass flow constraints will exclude the possibility of removing aluminum from the waste stream via a mixed waste MRF and then sending the recovered aluminum to a landfill. The user can identify

the objective as minimizing total cost or life-cycle parameter (e.g., energy consumption, carbon equivalents, CO, CO₂, NO_x, particulate matter, and SO_x). The optimization module uses linear programming techniques to determine the optimum solution consistent with the user-specified objective and mass flow, and user-specified constraints. Examples of user-specified constraints are the use of existing equipment/facilities, and a minimum recycling percentage requirement.

The GUI consists of Microsoft Visual Basic routines that act to pull all components of the model together to allow easy user manipulation of the spreadsheet models and the optimization module. It allows additional user constraints to be specified and provides a graphical representation of the solid waste management alternatives resulting from the optimization. Results are presented on a cost or pounds of emission per ton basis and can be viewed at the system level, unit process level, or MSW component level.

1.3 WHAT ARE THE HARDWARE AND SOFTWARE REQUIREMENTS?

The DST is a large and complex model that requires a high end computer and some special software to run properly. This section describes the recommended hardware and software needs for running the DST.

Hardware

To adequately run the DST, users will need a Pentium II PC compatible machine with at least a 16 gigabyte hard drive, 512 of RAM, 400MZ processor, and preferably a 17 inch color monitor. Machines with less memory or processing capacity may be used but will result in slower run times for the DST.

Software

Users will need Microsoft Office 97 and a license for a commercial software package called Cplex to run the DST. Microsoft Office 97 is a standard software package. Cplex is a linear optimization solver package that is used by the DST to search and find optimal solutions to MSW management strategies based on a user defined objective (e.g., minimize cost) and any other user defined constraints (e.g., specified landfill diversion rate). Without Cplex, you will not be able to use the DST.

Instructions for obtaining a copy of Cplex to be determined. (This will depend on how the tool is distributed)

1.4 HOW DO I GET THE TOOL?

To be determined.

1.5 IS THE TOOL COMPLICATED TO USE?

The model is fairly complicated to use, but technically oriented people should be able to familiarize themselves with it in a short time. Searching for management strategies that optimize cost or a particular LCI parameter presents a complex problem with many different management options and possible flows for individual components of MSW. Providing users with sufficient flexibility to conduct their own analyses leads to a multifaceted model. Once you understand how the model functions, you will be able to conduct your own analysis on this complex issue.

1.6 HOW CAN I GET ASSISTANCE ON USING THE TOOL?

The DST contains many features to assist you in using the tool. These include notes on individual cells and an extensive on-line help system. To access the help system, simply press the help button on any screen or from the menu. Technical support other than the on-line help available in the tool is to be determined by its commercialization.

1.7 WHAT TYPE OF INPUT DATA WILL I NEED TO RUN THE TOOL?

Although the DST includes default data values for most input parameters, it was designed to allow the user to tailor the tool to a specific community or region using site-specific information. Some of the basic types of information that we recommend the user develop when using the DST include the following:

MSW Generation and Percent Composition

The first area of information that is needed to run a scenario of a MSW management system is the total amount of waste generated per year. This can be supplied as a total tonnage, or as a calculation based on generation rates (pounds per person per day) and population totals. Additionally, we recommend that users determine the percent composition, or the percentage of the waste which is comprised of each of the 48 constituents listed in Section 2.

Sector Breakdown

The DST can model two residential, two multi-family dwelling, and ten commercial waste generation sectors. The two residential and multi-family sectors may be broken down into urban and rural sectors, or some other method that represents sectors with similar waste characteristics. The ten commercial sectors may be broken down by retail, manufacturing, hospitals, etc. Because a material flow will be developed for each sector, it is useful to break down the community in a manner where waste-flow data are available.

Management Options

There are seven management activities that can be modeled by the current version of the DST: collection, transfer stations, MRFs, combustion, RDF, composting, and landfills. Within each of these management activities, there are a number different options and designs. For example, there are 20 possible collection options, 8 types of transfer stations, 5 MRF designs, and 3

compost facility designs. These management options and designs are listed and described in Section 3 of the manual. Users should specify which management activities and designs are applicable to each sector of their community.

Material Flow

To develop a baseline model within the DST it is necessary to determine the material flow of MSW throughout the community or region under study. This waste flow should consist of the total tonnage and percent composition of MSW in each management option, for each sector. More specifically, this means the total tonnage and percent composition of waste generated, collected by each collection option, recovered by each type of MRF, and discarded by each type of disposal activity. This waste flow should be determined for each sector, separately. See Section 5 for a sample material flow.

Additional Input Parameters

There is additional information that, if available, may be used as override values for the default values of the DST. Some key parameters include:

- Market value of recyclables
- Landfill tipping fee
- Distance between houses on the residential collection route
- Distance between end of route and various disposal facilities
- Time to load vehicle at collection location
- Time to unload at various disposal facilities

1.8 ORGANIZATION OF THIS USERS MANUAL

This manual is designed to provide the user of the DST with the essential information required to use the tool to operate the model and conduct scenario analyses of integrated municipal solid waste (MSW) management strategies. A number of supporting documents are available from EPA if you would like to know more about the methodologies, data, and assumptions behind the model.

A life-cycle model must begin with a rigorous definition of the system that has been modeled. The system description for this model is presented in Section 2. The DST includes a number of components including waste flow equations, an optimization routine, and process models. An overview of the process models embedded in the DST is presented in Chapter 3. Chapter 4 contains a discussion of appropriate uses of the model and its limitations. The user is cautioned to study Chapter 4 carefully before using the model to insure that the model is not misused and the results are interpreted and used correctly. Chapter 5 walks the user through an example case study.

Section 2

System Description

This Section describes the overall system and the system boundaries that have been defined and implemented in the DST and which are used to conduct the life-cycle inventory (LCI) and cost analysis of municipal solid waste (MSW) management alternatives.

The overall system is divided into a number of distinct MSW management processes linked together as illustrated in **Figure 2-1**. These processes include waste generation, collection and transfer, separation, treatment, and burial. Remanufacturing is considered to the extent that a specific component of the waste stream is recycled. In this case, the LCI will include energy and resource consumption and the environmental releases offset by virtue of using recycled versus virgin materials.

Although **Figure 2-1** illustrates the functional elements which comprise the MSW system, the key unit operations in the system and the manner in which waste can flow between these unit operations are illustrated in **Figure 2-2**. As presented in **Figure 2-2**, there is a lot of interrelatedness between the individual unit operations. For example, decisions made with respect to waste collection and separation influence downstream processes such as combustion. An example of waste management alternatives for one waste component is presented in **Figure 2-3**. This figure illustrates the possible paths for old newsprint (ONP) through the system.

In defining the MSW management system, the objective was to be as flexible as possible. However, given the large diversity of settings in which MSW is generated in the United States, development of a single system definition to address all situations would be overly complicated. Thus, there are likely to be situations where this system definition cannot be applied. See Section 4 of this manual for more information about applications and limitations of the tool.

2.1 SYSTEM BOUNDARIES

The system has largely been defined through the description of the functional elements and unit operations, as presented in this Section, and the manner in which each will be treated. A summary of the system boundaries are provided below. This explains how and why the boundaries for the environmental (LCI) analysis are different from the boundaries used for cost analysis.

Insert Figure 2-1. Overall System

Insert Figure 2-2. Example System Flow for Newsprint

2.1.1 General Boundaries for LCI

In general, the boundaries for the LCI include all data which have a bearing on the system from materials acquisition through waste disposal or remanufacturing. Where a material is recycled and a new product is produced, the resources, energy, and environmental releases associated with production of the new product, as well as those saved by using a recycled material instead of a virgin material, will be considered. This concept also applies to energy recovery from combustion and described in more detail in Section 3 of this manual.

In considering remanufacturing, the tool includes LCI parameters from the recovery of a raw material through its conversion to an intermediate product (e.g., aluminum ingot, plastic pellet). Where petroleum is a raw material, the analysis includes all activity beginning with recovery of petroleum from the earth. Where energy is required in a process, the energy associated with production of the energy (precombustion energy) and the wastes associated with energy production will be considered. Where trees are utilized, resources associated with growing and harvesting the tree will be considered.

The functional elements of MSW management include numerous pieces of capital equipment from refuse collection vehicles to balers to major equipment at paper mills. Resources are associated with the fabrication of capital equipment as well as the construction of a new facility. In theory, these resources should be considered in the LCI. This may be particularly relevant in evaluation of waste management strategies which suggest the construction of a new facility, such as a MRF, or the purchase of new refuse collection vehicles. Although the inclusion of capital equipment appears to be theoretically correct, it introduces additional complexity which may not be necessary. Sensitivity analysis was used as a screen to evaluate the importance of its inclusion in the LCI and it was determined to not be of significance to the overall LCI results and thus was excluded from the LCI analysis.

Another system boundary is at the waste treatment and disposal end of the system. Where liquid wastes are generated which require treatment, the energy associated with their treatment will be considered. For example, if BOD is treated in an aerobic biological wastewater treatment facility, then energy is consumed to supply adequate oxygen for waste treatment. If a solid waste is produced which requires burial, energy will be consumed in the transport of that waste to a landfill and its burial in the landfill. In the case of compost where the compost product is applied to the land as a soil amendment, the LCI includes the emissions (leachate) associated with the land application.

2.1.2 General Boundaries for Cost Analysis

The system boundary for cost analysis differs from that of the LCI in that it focuses on the cost of waste management as experienced by the public sector. Thus, the cost analysis will include the cost of waste collection, transfer stations, MRFs, composting facilities, combustion, RDF plants, and landfills. In addition, where a waste is produced as part of a waste management facility, the cost of waste treatment will be included in the cost analysis of that facility. For

example, we will include the cost of leachate treatment in our cost analysis of landfills. The cost analysis boundary will also include the cost of educational or other materials associated with source reduction or other aspects of solid waste management.

The boundary for the cost analysis will be drawn at the points where waste is buried and recyclables are shipped to a downstream processor. For example, if recyclables were shipped from a MRF, the cost analysis would end where the public sector received revenue (or incurred a cost) in exchange for recyclables. The same analysis would apply to the sale of RDF or electricity. The user must be cautioned that there are situations where the revenue realized from the sale of a recyclable is artificially high. This has occurred in the past where a manufacturer has taken steps to encourage the recycling of a material by offering an artificially high price. Such situations may arise when recycling of a waste component not typically recycled begins. This situation would not be expected to persist for a period of several years.

One cost to be excluded from the cost analysis is the cost of remanufacturing. However, we feel that this cost is reflected in the price paid to a community for recyclables or electricity. Another cost to be excluded is the cost associated with the collection and processing of waste generated in the private sector. We assume that waste generated in the commercial sector is collected by private haulers at the expense of the waste generator. If this waste is transported to a facility operated in the public sector, then a tipping fee will be paid to reflect the cost of waste management at that facility. Thus, the cost of commercial waste disposal is not charged to the public sector. Nevertheless, it is important to account for commercial waste as its mass is likely to be a significant component of total waste generation and it will affect the size of various facilities.

The user has the option to enter costs directly if known, or provide sufficient design information to estimate costs. Where costs are estimated, we propose to estimate costs in the absence of an allowance for profit. A profit margin could be specified if the user expects that a waste management unit operation will not be operated in the public sector. The calculated cost is then adjusted upwards prior to its use.

In summary, by focusing on costs incurred in the public sector, the analysis will be of most use to local officials responsible for development of strategies for solid waste management.

2.2 WASTE GENERATION

The system for this project includes a subset of wastes defined as MSW by the U.S. Environmental Protection Agency (EPA) in their waste characterization studies (see EPA, 1997). This definition includes waste generated in the residential, commercial, institutional and industrial sectors but excludes industrial process waste, sludge, construction and demolition waste, pathological waste, agricultural waste, mining waste and hazardous waste. Ash generated from the combustion of MSW, however, is included in the system.

The MSW stream has been divided into three waste categories: residential, multifamily

dwelling, and commercial. The logic for this separation is that different collection and recycling alternatives apply to each category. The third category of waste defined here is commercial waste which includes MSW generated in offices, institutions, industries, etc. Arrangements for the collection of this waste are typically handled by the waste generator and are unlikely to overlap with the collection of residential and multifamily dwelling waste. However, these wastes typically enter the same system that handles residential and multifamily dwelling waste at some point in their management.

The composition of waste from the residential, multifamily and commercial sectors will likely differ. In developing a scenario for evaluation in the DST, the user has the opportunity to input the waste generation rate and composition for each of the waste generation sectors. Default data will be provided for each category. We recognize that such data may be difficult for the user to obtain for commercial waste. However, the composition and generation rate for commercial waste is extremely site specific and default data are not likely to be reliable. Ideally, commercial waste generation factors would be provided by SIC code. However, the development of such factors was beyond the scope of this project. Should such factors be developed by others, the commercial waste component of the tool could be modified to incorporate SIC codes.

2.2.1 Source Reduction

Source reduction represents the difference between potential and actual waste generation. Source reduction are designed to “reduce the volume or toxicity of the waste stream, including the design and manufacture of products and packaging with minimum toxic content, minimum volume of material, and/or a longer useful life” (EPA, 1997 - Source Reduction Program Potential Manual). By virtue of reducing the amount of waste managed by a particular system, source reduction may will typically lead to reductions in cost and LCI parameters.

There are two components of source reduction that affect the waste management system:

- LCI aspects of not producing the materials that are source reduced, and
- Cost and LCI aspects from managing a smaller quantity of waste in the system, e.g., collection costs and LCI may be lower due to the smaller quantity of waste being collected.

LCI data are used in the DST to calculate the potential LCI benefits of recycling. These same data can also be used to obtain rough estimates of potential LCI benefits resulting from certain source reduction activities. The waste management cost and LCI aspects of source reduction can be estimated by recalculating the new waste generation and composition rates (after source reduction) and then using the DST to estimate the new waste management LCI.

Source reduction activities that can be handled in this manner include:

- Reduction in the use of a specific materials through product redesign or lightweighting.
- Substitution of specific materials for others (applies only to those materials for which we currently have data).

For reductions in the use of a specific material through product redesign or lightweighting, if the redesign of an aluminum can reduces the amount of material used, then we would calculate the LCI benefits associated with the smaller quantity of aluminum used. The quantity of source reduced aluminum would have to be estimated by the user.

For substitutions, we can only handle materials for which we currently have manufacturing LCI data (aluminum, glass, paper, plastic, steel). As an example, we have data to calculate the LCI benefits (or additional burdens) associated with replacing a defined quantity of aluminum with PET. However, we cannot calculate the LCI benefits (or additional burdens) associated with replacing a defined quantity of aluminum with a wood-plastic composite because manufacturing data for this composite material is not currently in our data set.

Source reduction activities that cannot currently be handled by the DST include:

- Substitution of specific materials for which we do not have manufacturing LCI data.
- Backyard composting (no data to support emissions from backyard compost or substitutes such as fertilizers and pesticides).
- Household reuse of materials (no data to support emissions from household processing of materials, such as washing).

In addition to the effects that source reduction may have on the LCI component of the DST, there may also be a cost outlay from the local government to promote and educate others about source reduction. Therefore costs to communities associated with source reduction should be added to the total cost of waste management for the modeled community.

To implement source reduction in the DST, a menu option titled “Tools” was added to the DST’s main interface. When the user selects the Tools menu, and selects Source Reduction from the menu, an input worksheet will open where the quantities of specific materials source reduced are entered. The user will then need to appropriately modify the waste generation and composition input data based on their specified level of source reduction. EPA’s Source Reduction Program Potential Manual (EPA, 1997) may be used to estimate the quantity of waste reduced through different source reduction activities. After the quantities of materials that are Source Reduced are entered, the user can view “savings” in emissions and energy use achieved by source reduction by clicking on the emission category of interest from the screen.

The DST allows users to generate approximate source reduction benefits and compare source reduction benefits to the cost and LCI of the waste management system. The approach taken to evaluate source reduction is consistent with that used in EPA’s Waste Reduction Model (WARM).

To capture the cost and LCI aspects of managing a smaller quantity of waste, the waste generation and composition input data have to be modified based on the specified level of source reduction.

The user should note that the effects of source reduction associated with the design and manufacturing of products or packaging are unique to specific materials and are not included in the decision support tool. Collection of data on specific industrial processes for evaluation of source reduction was beyond the scope of this project. If the user has information about how design and manufacturing modifications affect the amount of waste generated, that information can certainly be used to adjust the waste generation data input into the tool to assess the effects of the source reduction, as described above.

2.2.2 Backyard Composting

Yard waste and food waste that is composted by homeowners in a backyard composting unit represents waste that is and can be diverted from entering the waste stream. Other methods, such as grass mulching, can also be used to reduce the amount of organic waste. The front end of the system boundary is defined to be the point at which MSW is set out at a curbside pickup or dropoff location. Thus the cost and environmental burdens associated with backyard composting are not included in the decision support tool.

If a user wishes to assess the affect of backyard composting programs, this can be done in a similar manner to source reduction. In short, the a user would conduct a runs of the tool with and without a backyard composting to see the effects on public costs. The affect that home composting and other home waste reduction activities has on the waste generation rate can be estimated using guidance from EPA's Source Reduction Program Potential Manual (EPA, 1997)

The user should note that although this approach may make sense for evaluating cost affects, it would be difficult to conduct a parallel analysis for environmental burdens unless the user had reliable emission estimates for backyard composting.

2.2.3 In-Home Recyclables Washing and Separation

The manner in which residential and multifamily dwelling waste are collected will influence resource consumption (e. g. water, electricity) in households. Several of the collection alternatives described in the following section include source separation of recyclables. Where a collection alternative involves the separate setout of recyclables, they may be rinsed for in-home storage prior to setout at curbside. Again, because the front end of the system boundary is defined to be the point at which MSW is set out at a curbside pickup or dropoff location, water and energy use and wastewater production associated with this activity are not included in the system boundaries.

2.3 WASTE COMPOSITION

MSW has been divided into individual components as listed in Table 2-1. The rationale for the selected components is described here. The residential and multifamily dwelling waste streams

have been divided into 39 components. The components were selected to include those items which are most commonly recycled such as old newsprint (ONP) and HDPE milk and water containers. In addition, the categories have been selected to allow for flexibility by the addition of “other” categories. For example, two extra categories are allowed for “other paper.” If the user wishes to consider the recycling of a paper component(s) not listed in Table 2-1, then the composition of that waste component can be accounted for in a “paper-other” category.

Similarly, if the user does not wish to consider recycling of a component, such as office paper from residential waste, then the user simply enters its composition as 0%. Two “other” categories have been added for plastics, paper and aluminum and a single “other” category was added for ferrous metal in the residential and multifamily dwelling waste streams.

The waste components listed in Table 2-1 are the same for residential and multifamily dwelling waste. However, different compositions for each waste component may be used if desired. The commercial waste stream has been defined to include ten specific components and two miscellaneous categories. These components include the major recyclables in commercial waste based on national averages (office paper, old corrugated containers), materials which are commonly recycled (aluminum cans, phone books, third-class mail, PET beverage bottles, container glass and newsprint), two “other” categories and non-recyclables.

Although wastes are listed as individual components in Table 2-1, there are cases where wastes can be grouped together. The system is mathematically defined to allow consideration of mixed color glass recycling in addition to recycling by individual color. Of course, recycling of mixed color glass would be dependent on the availability of a market. The user has the option to input the revenue associated with mixed color glass, as well as the opportunity to remove from consideration mixed color glass recycling. Similarly, the user can allow consideration of mixed paper or mixed plastic recycling. In the case of mixed paper and mixed plastic, the user is required to specify whether the recyclables are used in remanufacturing or as a fuel.

For waste generation, the user can input generation and composition data, as described in this and the previous section. Default data on physical and chemical characteristics of each waste component such as density, Btu value, and moisture content are provided in the tool’s default data set. These data will be used to calculate characteristics of the waste stream, such as moisture content and Btu value, as a function of waste composition.

Table 2-1. Components of MSW Considered in the System

Residential Waste	Multifamily Dwelling Waste	Commercial Waste
Yard Waste	Yard Waste	1. office paper
1. grass	1. grass	2. old corrugated containers
2. leaves	2. leaves	3. phone books
3. branches	3. branches	4. third class mail
4. food waste	4. food waste	5. aluminum cans
Ferrous Metal	Ferrous Metal	6. clear glass
5. cans	5. cans	7. brown glass
6. other ferrous metal	6. other ferrous metal	8. green glass
7. non-recyclables	7. non-recyclables	9. PET beverage bottles
Aluminum	Aluminum	10. newspaper
8. cans	8. cans	11-12. other recyclables
9-10. other - aluminum	9-10. other - aluminum	13-15. other non-recyclables
11. non-recyclables	11. non-recyclables	
Glass	Glass	
12. clear	12. clear	
13. brown	13. brown	
14. green	14. green	
15. non-recyclable, non-container glass	15. non-recyclable	
Plastic	Plastic	
16. translucent-HDPE	16. translucent-HDPE	
17. pigmented-HDPE bottles	17. pigmented-HDPE bottles	
18. PET beverage bottles	18. PET beverage bottles	
19-24. other plastic	19-24. other plastic	
25. non-recyclable plastic	25. non-recyclable plastic	
Paper	Paper	
26. newspaper	26. newspaper	
27. office paper	27. office paper	
28. corrugated containers	28. corrugated containers	
29. phone books	29. phone books	
30. books	30. books	
31. magazines	31. magazines	
32. third class mail	32. third class mail	
33-37. other paper	33-37. other paper	
38. paper - non-recyclable	38. paper - non-recyclable	
39. miscellaneous	39. miscellaneous	

2.4 WASTE MANAGEMENT PROCESSES

The waste management processes that are included in the system are as follows and are described in detail in Section 3 of this Manual:

Collection: There are a number of options for the collection of refuse generated in the residential, multifamily dwelling and commercial sectors. The manner in which refuse is collected affects the cost, resource utilization, releases and design of both the collection operation and potential down stream processing facilities such as a materials recovery facility (MRF). Multifamily dwelling waste may or may not be collected by the city in a manner similar to residential refuse collection. Whether this waste is collected by the city or a private contractor should not affect the LCI. We assume that commercial waste and recyclables are collected by private contractors. However, the energy and resource consumption, and environmental releases associated with commercial waste and recyclables collection will be accounted for in the proposed system. The construction of waste or recyclables collection bins is not included in the system boundaries.

Transfer Stations: Once refuse has been collected, there are a number of facilities to which it may be transported including a transfer station, MRF, a combustion facility, RDF plant, composting facility or a landfill.

Material Recovery Facilities: In MSW management strategies where materials recycling is utilized, recyclables will require processing in a MRF. The design of a MRF is dependent upon the manner in which refuse is collected and subsequently delivered to the MRF. Thus, the collection and recycling of MSW are interrelated. This interrelatedness is captured in the system.

Composting: Composting is the aerobic biodegradation of organic matter and is considered as a treatment alternative. The compost process model can consider the composting of yard waste and mixed waste. Yard waste composting may occur in either a centralized municipal facility or in a generator's backyard. Here, we consider a centralized composting facility. Backyard composting is not included in the system boundaries. We propose to consider two alternatives for yard waste composting; a low medium technology facility. The major difference between these two facilities is the degradation rate of the yard waste as influenced by the turning frequency. The design of the mixed waste composting facility can be based on mechanical or static aeration.

Combustion: Combustion represents a treatment alternative in which the volume of MSW requiring burial is significantly reduced. We consider a waste-to-energy (WTE) combustion facility in which MSW is burned with subsequent energy recovery in the form of electricity. Facilities in which energy is not recovered as well as facilities in which energy is recovered as steam are excluded from the system. The rationale for this selection is that the majority of combustion facilities constructed today include energy recovery as electricity.

Refuse Derived Fuel And Process Refuse Fuel: In addition to combustion as discussed in the previous section, two alternatives for recovery of the energy value of MSW will be considered in the solid waste management system, RDF and co-combustion. In the system described here, RDF production refers to the separation of MSW into a product stream with a relatively high BTU value and a residual stream with a relatively low BTU value. Of course, the efficiency of the separation of MSW into these streams will be less than 100%. There are many variations on the RDF theme including the production of shredded refuse for direct combustion, and the production of pellets for shipment over longer distances. The most common RDF processes will be identified in future work so that one or more generic RDF plant designs can be developed. These designs will be used as the basis for which cost, energy, and emission factors are developed.

Landfills: Three types of landfills will be considered in the system; one designed as a traditional mixed waste landfill, one enhanced bioreactor landfill, and a second designed for the receipt of ash only. The mixed refuse landfill will be designed according to RCRA Subtitle D and Clean Air Act standards. However, the user will have the opportunity to specify either a more lenient or stricter design with respect to the liner and cover systems. The landfill will be operated as a dry landfill. Consideration of the operation of a landfill with leachate recycle for enhanced decomposition and methane production was discussed in the previous section. The system will include both gaseous and liquid releases from the landfill. The user will be required to specify whether gas is flared, recovered for energy, vented to the atmosphere or allowed to diffuse out of the landfill. This information, coupled with data on landfill gas production, will be used to estimate atmospheric emissions. Estimates will also be developed for the amount of leachate requiring treatment. This leachate will be treated in an offsite treatment facility. Energy and emissions associated with leachate treatment will be considered in the LCI.

2.5 ADDITIONAL SYSTEM PROCESSES

Remanufacturing: As part of the LCI, we must account for all resources, energy, and environmental releases associated with the recycling and reprocessing of a waste component. This section presents the conceptual framework which we propose to use to account for resource expenditures and potential savings due to the use of recycled materials. In management strategies where some portion of the MSW is recycled, the recyclables will ultimately be delivered to a facility for remanufacturing. Separation will occur during collection, at a MRF, or at another waste management facility. In addition to recycled materials, an offset will also be required in management strategies where energy is recovered from either the direct combustion of MSW, RDF, or landfill gas. The conceptual framework described above may be applied here as well. Energy recovered from the MSW will be credited to that management strategy. In calculating emissions reductions associated with energy recovery, we assume that any “saved” electrical energy resulted from fossil fuel (coal, oil, or natural gas) and not from hydro or nuclear power.

Electrical Energy: The electric energy model provides an accounting of the total energy consumption and emissions resulting from the use of electric energy. Precombustion and combustion energy consumption and emissions on a per unit fuel basis are used in conjunction with unit efficiencies, transmission and distribution line losses, and electric generation fuel usage percentages to allocate energy consumption and emissions to the usage of an electric kilo-watt hour (kWh) based on the contribution to the generation of that kwh by each fuel type. Emissions and energy consumption per kwh are calculated for the national grid fuel mix as well as for the nine major electrical generating regions in the United States. Default values for parameters used in these calculations are provided with optional user override capability for the majority of these parameters.

Transportation: Transportation (separate from waste collection) modes included in the system are rail, heavy-duty diesel (tractor trailers), light-duty diesel vehicles and light-duty gasoline vehicles. Cost and LCI factors for transport of mixed refuse, fuel, and compost are calculated per ton of aggregate mass flow between nodes. In contrast, recyclable materials are often shipped separately and have item-specific densities. For example, loose glass has a density nine to ten times that of plastic. For this reason, item-specific cost and LCI factors are calculated for recyclables transport. Connections for which item-specific factors are determined for recyclables include transport from transfer stations to separation facilities and from separation facilities to remanufacturing.

2.6 DATA PARAMETERS TRACKED

The main categories for cost and environmental parameters tracked as part of the research included:

Cost Categories:

- Annual capital cost
- Annual operating cost

Environmental (LCI) Categories:

- Energy consumption
- Air emissions
- Waterborne releases
- Solid waste

To compare across alternative MSW management options, we can only use parameters for which comparable data exists across all unit processes. For example, although data for dioxin/furan emissions for MSW combustion facilities are readily available, comparable data do not exist for MRF, composting, and landfill operations. Thus, we cannot directly compare these unit processes based on dioxin/furan emissions.

A subset of the parameters in the DST for which we currently have consistent data on can be optimized:

- Annual cost
- Carbon monoxide
- Carbon dioxide (fossil - resulting from the combustion of fossil fuels)
- Carbon dioxide (biomass - resulting from the biodegradation or combustion of organic material)
- Electricity consumption
- Greenhouse gas equivalents
- Nitrogen oxides
- Particulate matter
- Sulfur dioxide

These parameters can be optimized on as part of the decision support tool (DST) solution, as described in Section 5. Additional air and water parameters are tracked and reported in the DST, but cannot be optimized on at this time. Based on the need of user to optimize on additional parameters, future versions of the DST can be updated to include an expanded list of optimizable parameters.

Section 3

Process Model Descriptions

Of the four main components of the decision support tool -- materials flow model, process models, optimization routine, and user-interface -- the process models are where the cost and LCI methodologies are implemented. This Section of the User's Manual provides a summary for each process and discusses key input and default parameters for each.

The process models are essentially mathematical representations of each waste management processes (e.g., mixed MSW collection, yard waste composting, mixed waste combustion with energy recovery) based on generic design and operating information. Process models have also been developed for other system processes such as electrical energy generation, transportation, and remanufacturing of recycled materials. The output of each process model is a set of coefficients for cost and LCI burdens including energy consumption, air emissions, water pollutants, and solid waste. These coefficients are presented per individual component of the MSW stream. By using these models, cost and environmental burdens of managing individual components of MSW in alternative management strategies can be analyzed.

As illustrated in **Figure 1-1**, there are multiple places in the decision support tool where the user can input site-specific information. Each process model has its own set of data which the user can interact with through the data input manager of the decision support tool, as illustrated in **Figure 3-1**. This feature of the tool enables users to access, review, and enter site-specific information for each process model to tailor an analysis to a particular municipality or region. The data input manager has been structured using sub-interfaces which are grouped in a hierarchical manner to allow users to easily access and input data. The highest level interfaces are grouped by the unit operations (e.g., collection, MRF, composting, and landfill, etc.). The next level interfaces are grouped by data type (e.g., scheduling, labor, equipment, etc.). Subsequent levels allow the user to input data on the details of scheduling, labor, and equipment costs etc. Navigation through these subinterface screens has been made easy through the use of simple mouse operations and pull-down menus.

3.1 COLLECTION PROCESS MODEL

The collection process model calculates cost and LCI coefficients for the collection and transport of MSW and recyclable materials from the curbside (or dropoff) to a downstream waste management operation. There are a large number of different collection options and collection combinations included in the decision support tool which the user can tailor by inputting site-

Input Manager

- [-] Add/Delete sectors
 - [+] Residential
 - (New Sector)
 - [+] Multi-family
 - (New Sector)
 - [+] Commercial
 - (New Sector)
 - [+] Generation
 - [+] Generation rate parameters
 - [+] Composition
 - Mixed paper definition
 - Mixed plastic definition
 - [+] System-Wide Inputs
 - [+] MSW properties
 - Heating value
 - Combustion residuals
 - [+] Economic parameters
 - [+] LCI
 - Greenhouse gas equivalents
 - [+] Collection
 - [+] General
 - Wages & Overhead
 - Garage/Office
 - [+] Vehicle

Generation\Composition\Residential - MSW System1

File Edit View Insert Format Tools Data Wind

Sector 1

Waste component	Residential Composition (Fr by weight)
	Default
Yard Trimmings, Leaves	0.071
Yard Trimmings, Grass	0.141
Yard Trimmings, Branches	0.071
Old News Print	0.111
Old Corr. Cardboard	0.023
Office Paper	0.015
Phone Books	0.003
Books	0.008

Examples of data input categories

Default data with reference information are provided where possible. A user can always choose to override defaults

Figure 3-1. Data Entry Through the Input Manager
A user can enter site-specific data, e.g., waste composition, using the Input Manager

specific data for such parameters as distances between collection points, labor wages, speed of collection vehicles between stops, and compaction factors for recyclables.

The manner in which MSW and recyclable materials are collected affects the cost, resource utilization, environmental releases, and design of both the collection operation and potential downstream processing facilities such as a material recovery facility (MRF). The methodology used for the collection process model is presented in the following sections as a generic methodology. The results of the collection process model are used in the decision support tool to calculate the total system cost and LCI for MSW management alternatives that involving defined collection options.

Conceptual Designs for Collection

To account for the many different ways in which MSW and recyclable materials are collected from residential, multifamily dwellings, and commercial sectors, the decision support tool includes 21 different collection options designated as C0 through C20. Definitions for each option are as follows:

Collection of Refuse and Recyclables from Residential (single-family dwellings)

Mixed Refuse Collection

- C1.** Collection of mixed refuse in a single-compartment truck with no separation of recyclables.

Recyclables Collection

- C2.** Set out of commingled recyclables that are sorted by the collection vehicle crew at the point of collection into a multicompartment vehicle.
- C3.** Collection of recyclables presorted by the generator into a multicompartment vehicle.
- C4.** Collection of commingled recyclables in a vehicle with two compartments: one for paper recyclables and the other for nonpaper recyclables.

Co-Collection

- C5.** Collection of mixed refuse and recyclables in different colored bags for transport in a single compartment of a vehicle. Paper recyclables are placed in one blue bag, and nonpaper recyclables are placed in a separate blue bag. Bags are sorted at a MRF.
- C6.** Collection of mixed refuse, paper recyclables, and nonpaper recyclables in three

separate compartments of the same vehicle. The refuse and recyclables would then be delivered to a MRF, and the mixed refuse would be delivered to a combustion facility, composting facility, refuse-derived fuel (RDF) plant, or landfill.

Residuals Collection

- C7.** If recyclables are collected in options 2, 3, or 4, then residual MSW is collected in a single-compartment vehicle as in option 1.

Recyclables Drop-Off

- C8.** This alternative allows for the waste generator to bring recyclables to a centralized drop-off facility. This could also be a buy-back center.

Yard Waste Collection

- C0.** Curbside collection of miscellaneous yard waste (leaves, grass clippings, branches) in a single-compartment vehicle.
- C9.** Curbside collection of leaves only using a leaf vacuum truck.
- C10.** Dedicated collection of leaves in a vacuum truck. This alternative allows for the waste generator to bring yard waste to a centralized composting facility.

Wet/Dry Collection

- C11.** Wet/dry collection with recyclables included with the dry portion. The user will be asked to specify whether various paper types are to be included in the wet or dry collection compartments.
- C12.** Wet/dry collection with recyclables collected in a separate vehicle. The user will be asked if various paper types are to be included in the wet or dry collection compartments.

Collection of Refuse and Recyclables from Multifamily Dwellings

Mixed Refuse Collection

- C13.** Collection of mixed refuse from multifamily dwellings in a single-compartment truck. The user will be required to specify the use of hauled or stationary containers.

Recyclables Collection

C14. Collection of presorted recyclables into multiple stationary or hauled containers.

C15. Collection of commingled nonpaper recyclables into a single bin for containers and a second bin for paper recyclables.

Residuals Collection

C16. If recyclables are collected in options 12 or 13, then residual MSW is collected in a single-compartment vehicle as in option 11.

Wet/Dry Collection

C17. Wet/dry collection with recyclables included with the dry portion. The user will be asked to specify whether various paper types are to be included in the wet or dry collection compartments.

C18. Wet/dry collection with recyclables collected in a separate vehicle. The user will be asked to specify whether various paper types are to be included in the wet or dry collection compartments.

Collection of Waste and Recyclables from Commercial Waste

Recyclables Collection

C19. Collection of presorted recyclables.

Mixed Refuse Collection

C20. Collection of mixed refuse before or after recycling.

To complete the cost and LCI methods, the number of collection vehicles needed to collect the waste and recyclable materials is needed. This is calculated by determining the number of collection locations at which a collection vehicle can stop along a collection route before it is filled to capacity. This number is multiplied by the amount of time that a vehicle spends stopped at each location and traveling between locations to yield the length of time that a collection vehicle takes to travel from the beginning to the end of its collection route. The length of time that a collection vehicle takes to make a complete collection trip includes the route travel time plus time spent traveling back and forth from the location where it unloads the material that it collects (landfill, material recovery facility, composting facility, etc.) and the time spent unloading at that location.

Next, the number of daily collection vehicle trips is calculated. The number of fully loaded trips that a collection vehicle can make during one workday is calculated after time is deducted for

travel to and from the vehicle garage at the end of each day and the beginning of the next day, for the lunch break, and other break time.

The next step is to divide the total number of collection locations in the area served by a collection option by the number of collection locations at which a vehicle stops during one collection trip to determine the number of trips needed to collect all the MSW generated in that area during one collection cycle. A collection cycle may represent one or more visits to each collection site per week, with a default value of one visit per week.

Once the numbers of daily collection vehicle trips and total collection trips are known, the number of trucks is determined by dividing total trips by daily trips and by the number of days per week that collection vehicles operate. The number of trucks is used to calculate the annual cost and LCI of the collection system, as described in the following sections.

Cost Methodology for Collection

The annual cost of collection is calculated from the number of trucks required and economic factors such as a vehicle's annualized capital cost, which is based on the purchase price amortized over service life; vehicle operating costs; labor costs; overhead costs; and costs for backup vehicles and collection crew personnel. Labor costs include the wages paid to drivers and collection workers. Overhead costs, which include administrative costs, are calculated as a function of the labor costs. Collection costs are divided into capital costs and operation and maintenance costs.

Capital Cost

Capital cost includes the cost of collection vehicles, backup vehicles, and an administrative rate that includes the capital cost of the garage and maintenance facilities. Capital cost is expressed in annual terms using a capital recovery factor that is dependent upon a book lifetime and discount rate.

Operation and Maintenance Cost

The operation and maintenance cost of the collection process includes the labor, overhead, taxes, administration, insurance, indirect costs, fuel cost, electricity cost, and maintenance cost. Overhead costs for labor are calculated as a fraction of labor wages. Overhead includes overtime, office supplies, fringe benefits, and temporary labor. The overhead rate is flexible and can be defined by the user to cover their specific labor situation.

LCI Methodology for Collection

The number of collection vehicles and other input parameters such as the miles traveled and fuel consumed are used in the collection process model to calculate the costs and release rates for LCI parameters as part of the decision support tool. Default or user inputted values for the speed that a vehicle travels while performing different tasks and its fuel consumption rate are used to determine how many miles it travels and how many gallons of fuel it consumes per day. These

in turn are multiplied by pollutant emission factors to arrive at values for the amounts of air pollutants, water pollutants, and solid wastes generated per ton of waste collected. The LCI calculations also include the consumption of electrical energy at the garage where the collection vehicles are housed and maintained. Resource consumption and environmental releases (air, water, and solid waste) associated with electricity use are accounted for in the LCI. In addition, LCI parameters are allocated by weight to individual components of the waste stream.

Energy

Fuel is consumed by collection vehicles to collect waste and recyclable materials. The quantity of fuel consumed in the collection process is calculated based on the fuel consumption rate of the vehicle type used and the quantity of waste or recyclables collected. Electrical energy is consumed as part of the collection process model for heating and lighting of the garage facility. The amount of electricity consumed is provided by standard consumption rates and is based on the size (square feet) of the garage.

Air Emissions

Air emissions in the collection process are from combustion of fuel in vehicles and from the production of energy used in the collection process. Air emissions data from fuel production processes and fuel combustion in collection vehicles during operation are included in the LCI.

Water Releases

Water releases associated with the collection process are releases from the production of energy used in the collection process and potentially from the washing of collection vehicles. Although the data input sheets include cells for waterborne release rates for washing of vehicles, the defaults are zero because we found this to be an insignificant source of releases.

Solid Waste Releases

Solid wastes due to collection include wastes released due to energy production (collection vehicle fuel and electricity). No process-related solid wastes are considered in the LCI for the collection process model.

3.2 TRANSFER STATIONS

Transfer stations are used in some MSW management strategies to more efficiently transport waste and recyclable materials from collection vehicles to various management options. The transfer station process model calculates cost and LCI coefficients for MSW and recyclables transfer stations. Costs and LCI parameters are calculated on the basis of user input and default facility design information and incorporates both the quantity and composition of the waste entering transfer stations. The results of the model are used in the decision support tool to calculate the total system cost and LCI for MSW management alternatives that involve transfer stations.

Conceptual Designs for Transfer Stations

The transfer station process model includes five types of roadway vehicle transfer stations and three types of rail transfer stations:

- TR1: Processing mixed MSW.** For mixed waste transfer stations, the user selects from five design options. The major differences between these design options are single- or multilevel design, the presence or absence of a compactor, and the type of rolling stock required.
- TR2: Processing commingled recyclables.** At a commingled recyclables transfer station, recyclables are loaded from collection vehicles into tractor trailers. As for TR1, the user can select from the same five transfer station designs. However, in all TR2 designs, paper recyclables are processed separately.
- TR3: Processing separately bagged mixed waste, nonpaper recyclables, and paper recyclables in a single compartment.** Single-compartment co-collection vehicles have paper recyclables in one bag, nonpaper recyclables in a second bag, and mixed refuse in a third bag in one compartment of the collection vehicle. Mixed waste is collected in black bags, and recyclables are collected in blue bags. The facility area for TR3 consists of a tipping floor for mixed black and blue bags, a storage area for separated blue bags, and separate loading areas for blue and black bags.
- TR4: Processing separately bagged mixed waste, nonpaper recyclables, and paper recyclables in separate compartments.** Three-compartment collection vehicles deliver source-separated mixed refuse (in black bags), nonpaper commingled recyclables (in blue bags), and paper recyclables (in blue bags) to TR4. Non-paper recyclables are unloaded onto a tipping floor and then paper recyclables are also loaded into a trailer with front-end loaders. Mixed refuse is directly tipped into a compactor via a hopper.
- TR5: Processing presorted recyclables.** A presorted recyclable transfer station is expected to operate at low capacities relative to other transfer stations. The facility is a simple design that includes a roof but no walls. Recyclables are unloaded into separate roll-on/roll-off containers with adequate collection vehicle maneuvering. A small backhoe is used for material handling. Full containers are removed from loading areas and stored on site until transported.
- RT1: Rail transfer of MSW from collection vehicles.** Mixed refuse is transferred from collection vehicles to a rail car at RT1. The user selects from two design options for RT1 transfer stations—the first is a one-level design and the second is a two-level design. For the one-level design, a crane is used to load containers. For the two-level design, refuse is pushed from the tipping floor into a compactor. The cost of rail spurs connecting the transfer station to existing local rail lines is included in the RT1 construction cost.
- RT2: Rail transfer of MSW from trains to landfill.** At the landfill rail haul transfer station, a crane unloads incoming containers of MSW into a storage area. Stored containers are loaded onto tractors, then hauled to the landfill working face. Tippers unload containers by inclining them greater than 60 degrees from horizontal.

RT3: Rail transfer of MSW from trains to enhanced bioreactor landfill. The design of rail transfer stations receiving containers at an enhanced bioreactor is the same as the design for RT2.

The following general description applies to all of the transfer station designs. Transfer stations require a covered structure that houses collection vehicle unloading areas, trailer- loading bays, refuse tipping floor space, and office space. Collection vehicles enter through a scale house, then proceed to unloading areas. Therefore, the site is partially paved to accommodate maneuvering of both collection and transport vehicles and container storage. Facility staff operate waste handling equipment to load and distribute refuse in hauling containers and to move refuse on the tipping floor. Office space includes an employee rest area and an administrative work area. The loading bay area includes a trailer footprint and trailer maneuvering space. The cost of refuse drop-off areas open to the general public is included in the construction cost for each design.

Cost Methodology for Transfer Stations

The cost of a transfer station depends on the design of station, the quantity and type of materials processed, and user input data (e.g., wage rates for transfer station workers). Costs are divided into capital costs and operation and maintenance costs.

Capital Cost

Capital cost consists of construction, land acquisition, engineering, and equipment cost that can be expressed in annual terms using a given capital recovery factor that is dependent upon a book lifetime and discount rate. For example:

- Construction cost includes the cost of the structure, paving, access roads, fencing, landscaping, and various other items. For rail transfer stations, the paving and site work includes the cost of all spurs that connect the facility to local rail lines. The cost of the structure includes support facilities such as office space and weigh stations. Construction cost is obtained by multiplying the floor area of the transfer station by the construction cost rate.
- Total area for a transfer station includes the area for the structure, access roads, fencing, weigh station, landscaping, etc. Total area multiplied with a cost rate gives the land acquisition cost.
- Engineering cost consists of fees paid for consulting and technical services for the transfer station planning and construction, and is estimated to be a fraction of the construction cost.
- Equipment cost consists of the capital and installation cost of equipment such as rolling stock and compactors.

Operation and Maintenance Cost

The operating and maintenance cost of the transfer station includes wages, overhead, equipment and building maintenance, and utilities. For example:

- Labor required for the transfer station consists of management, drivers, and equipment operators. In estimating the labor wages, it is assumed that part-time services can be hired. Management includes managers, supervisors, and secretaries. The wages paid for management are assumed to be a fraction of the wages paid to drivers and equipment operators.
- Overhead costs for labor are calculated as a fraction of labor wages. Overhead includes overtime, office supplies, fringe benefits, and temporary labor. The overhead rate is flexible and can be defined by the user to cover their specific labor situation.
- The cost of maintenance of equipment and structure is assumed to be proportional to the weight of materials processed in the transfer station.
- The cost of utilities (power, fuel, oil, etc.) is proportional to the weight of material processed in the transfer station.

LCI Methodology for Transfer Stations

The LCI methodology calculates energy consumption (or production) and environmental releases (air, water, and solid waste) from a transfer station and allocates these LCI parameters to individual components of the waste stream.

Energy

Transfer stations consume two main types of energy: fuels for rolling stock and electricity for equipment, lighting, and heating. The energy calculations for the LCI include both combustion and precombustion energy consumption. Combustion energy is the fuel or electricity consumed to operate rolling stock, lighting and heating. Precombustion energy refers to the energy consumed to produce the fuel and electricity used to operate the transfer station. The transfer station process model uses default or user-supplied data for fuel consumed by rolling stock, for heating and lighting purposes, and for processing equipment to calculate the total quantity of energy consumed per ton of material processed. Default data on the energy required to produce a unit of electricity, including its precombustion energy, are included in the electrical energy process model documentation.

Air Emissions

The transfer station process model accounts for airborne releases from two sources: (1) the pollutants released when fuel is combusted in a vehicle (combustion releases), and (2) the pollutants emitted when the fuel or electricity was produced (precombustion releases). Data for fuel and electricity generation production are included in the electrical energy process model documentation.

Water Releases

The transfer station process model accounts for waterborne pollutant emissions associated with the process related and precombustion water releases. Although there are placeholder cells in the input data sheets or process-related water releases as they relate to facility and equipment wash down but the defaults are currently set at zero. Default values for water releases from

energy production are provided in the electrical energy process model documentation.

Solid Waste Releases

The transfer station process model uses the energy consumed by equipment and heat and light of the transfer station building to calculate the solid waste generated. Solid waste generation is expressed in terms of pounds of pollutant per ton of material processed. Note that the solid waste referred to in this section pertains to the waste generated when energy is produced. Default values for solid wastes generated due to energy production are provided in the electrical energy process model.

3.3 MATERIAL RECOVERY FACILITIES

The materials recovery facility (MRF) process model calculates cost and LCI coefficients for the recovery of specific waste materials (e.g., aluminum, glass, paper, plastic, steel) from the MSW stream. The cost and LCI coefficients are calculated as a function of the quantity and composition of mixed or separated waste processed, user-defined inputs (e.g., number of hand sorters and their wage rates), and default information on the design of a MRF.

Conceptual Designs for MRFs

MRFs are used to recover recyclable materials from the MSW stream. The process flow in a MRF depends on the materials processed and the manner in which they are collected (e.g., mixed waste, mixed recyclable materials, separated recyclable materials). This is achieved by allowing the user to input a wide range of site-specific data about how waste and recyclable materials are collected. A critical element of the MRF design is the flexibility to process any composition of recyclable materials. This is necessary to allow the decision support tool solution to specify the materials to be recovered for a given objective. For example, the tool solution for a scenario run that designed to find the lowest cost solution will specify the specific materials and amounts to be recovered to meet the lowest cost solution.

There are eight possible MRF designs that may be included in the waste management system:

- MRF1: Mixed waste MRF.** This MRF processes mixed municipal solid waste.
- MRF2: Presorted recyclables MRF.** This MRF processes recyclables collected either presorted by the resident or sorted at the curbside by the operator of the collection vehicle.
- MRF3: Commingled recyclables MRF.** This MRF receives recyclables from a commingled recyclables collection program. All paper recyclables are collected in one compartment and nonpaper recyclables are collected in a separate compartment on the collection vehicle.
- MRF4: Co-collection MRF (single-compartment truck).** This MRF processes

commingled recyclables and mixed waste collected in a single- compartment truck. Recyclables are collected in a color-coded bag (blue) with mixed waste collected in a bag of a different color (black). All paper recyclables are placed in one bag and all nonpaper recyclables are placed in another bag. The colors of bags used in a city can be different, but blue and black are the two colors chosen for the discussions in this document and in the model.

- MRF5: Co-collection MRF (three-compartment truck).** This MRF processes commingled recyclables and mixed waste collected in a three-compartment truck. All paper recyclables are collected in bags that are placed in one compartment. Bags containing nonpaper recyclables are placed in the second compartment, and bags with residual mixed waste are placed in a third compartment. Recyclables are collected in blue bags and mixed waste is collected in black bags.
- MRF6: Front-end MRF to a composting facility.** This MRF is at the front end of a mixed waste composting facility (i.e., material recovery operations that precede composting operations). The MRF is similar to a mixed waste MRF but includes provisions for additional sorting to remove contaminants from mixed waste that affect the composting process or product quality.
- MRF7: Front-end MRF to an anaerobic digestion facility.** This MRF is at the front end of an anaerobic digestion facility (i.e., material recovery operations that precede anaerobic digestion operations). The MRF is similar to a mixed waste MRF but includes additional sorting to remove contaminants that could adversely affect the anaerobic digestion process or product quality.
- MRF8: Front-end MRF to a RDF facility.** This MRF is at the front end of a RDF facility (i.e., material recovery operations that precede RDF operations). The MRF is similar to a mixed waste MRF but does not include a magnet and eddy current separator for recovery of ferrous cans and aluminum cans. These waste components are recovered in a RDF facility.

All MRFs are based on the basic design (MRF 1) with minor differences to the other MRF designs based on the process flows of MRFs, which in turn depend on the type of MRF and the material being processed. For the basic design, mixed waste or recyclables are collected at curbside. Waste or recyclables that are collected in bags will pass through a debagging point in the MRF. The opening of bags can be done manually or mechanically. Loose material from the bag opening operation is then conveyed into an elevated and enclosed sorting room where the recyclables are recovered. The elevation of the sort room provides for space underneath for placement of bins into which separated recyclables are dropped. In a presorted MRF, non-glass incoming material is baled without sorting, and glass recyclables are loaded into trailers. For recycling collection options, paper recyclables, collected in separate bags, are conveyed to a paper sorting line.

In the sort room, pickers are positioned on both sides of a conveyer. Recyclables picked from mixed waste on the conveyer are dropped into chutes that lead into bins under the sort room. When a bin is full, it is replaced with an empty bin. The operation of moving a filled bin and replacing it with an empty one is done by rolling stock in the MRF. For non-glass recyclables, after a sufficient quantity of recyclables for making one bale is collected, these bins are emptied into the hopper of the baler that compacts the recyclables into a bale. The bale is then moved into a trailer at a loading dock. Storage space for bales is not provided within the MRF to conserve floor area.

Paper entering the mixed waste MRF as part of mixed waste is wet and contaminated. Thus, it is assumed that in a mixed waste MRF, only major components like cardboard and newsprint can be recovered separately. The remaining paper can be recovered only as mixed paper from mixed waste. In other MRFs, components of paper can be recovered individually from the paper sorting line. The "other" items for paper, plastic, ferrous, and aluminum allow the user to include recycling of additional components.

Glass recyclables are crushed as they pass through a crusher in the chute. Crushed glass is stored in bins. Once a bin is full, it is replaced with an empty bin. The filled bin is emptied into a trailer.

Metal cans remain in the refuse on the conveyer at the end of the sort room. Here cross belt arrangements are provided so that metal cans in the residue from all sort lines can be recovered by the same equipment (magnet for ferrous cans and eddy current separator for aluminum cans). Separation of aluminum cans can be manual or automated. If automated, an eddy current separator is used to recover aluminum cans.

The cross belt arrangements (used for metal recovery) can also be adjusted to lead recyclables directly into the hopper of a baler. This arrangement allows for a second sorting (for better quality) and baling of a separated recyclable. The second sort of recyclables can be done at the end of the workday. The user can specify the time required to remove contaminants from recovered materials.

Please refer to the complete MRF process model document for process flow diagrams and details for the eight MRF designs.

Cost Methodology for MRFs

The cost of a MRF depends on the type of MRF, the quantity and type of materials processed, and user input data. Costs are divided into capital costs, operation and maintenance costs, and revenue from the sale of recyclable materials.

Capital Cost

Capital cost consists of construction, land acquisition, engineering, and equipment cost expressed as an annual cost using a capital recovery factor that is dependent upon a book lifetime

and discount rate. For example:

- Construction cost includes the cost of the structure, access roads, fencing, landscaping, etc. The cost of the structure includes support facilities such as office space, a weigh station, and the loading conveyer. Construction cost is obtained by multiplying the floor area of the MRF by the construction cost rate.
- Total area for a MRF includes area for the structure, access roads, fencing, weigh station, landscaping, etc. Total area multiplied with a cost rate gives the land acquisition cost.
- Engineering cost consists of fees paid for consulting and technical services for the MRF planning and construction, and is estimated to be a fraction of the construction cost.
- Equipment cost consists of the capital and installation cost of equipment.

Operation and Maintenance Cost

Operating cost of the MRF include wages, overhead, utilities cost, and equipment and building maintenance. For example:

- Labor required for the transfer station consists of management, drivers, and equipment operators. In estimating the labor wages, it is assumed that part-time services can be hired. Management includes managers, supervisors, and secretaries. The wages paid for management are assumed to be a fraction of the wages paid to drivers and equipment operators.
- Overhead costs for labor are calculated as a fraction of labor wages. Overhead includes overtime, office supplies, fringe benefits, and temporary labor. The overhead rate is flexible and can be defined by the user to cover their specific labor situation.
- Utilities (power, fuel, oil, etc.) cost is proportional to the weight of recyclable materials processed in the MRF.
- The cost of maintenance of equipment and structure is assumed proportional to the weight of recyclable materials recovered in the MRF.

Residue Disposal Cost

Residue from the MRF is a result of the sorting efficiency being less than 100% and recovery of less than 100% of a recyclable. The cost of disposal of residue is based on the type of treatment or disposal facility (e.g., combustion or landfill) used.

Revenue from Sale of Recyclable Materials

Materials recovered in the MRF provide revenue that offset some of the cost of the MRF. The user can enter the sale price of recyclable materials from different MRFs in their MSW management system.

LCI Methodology for MRFs

The LCI methodology calculates energy consumption or production, and environmental releases (air, water, and solid waste) from a MRF and allocates these LCI parameters to the individual waste materials that are managed at the MRF.

Energy

MRF operations consume two main types of energy: fuels for rolling stock and electricity for equipment, lighting, and heating. The energy calculations for the LCI include both combustion and precombustion energy consumption. Combustion energy is the fuel or electricity consumed to operate rolling stock, lighting and heating. Precombustion energy refers to the energy consumed to produce the fuel and electricity used to operate the transfer station. The MRF process model uses default or user-supplied data for fuel consumed by rolling stock, for heating and lighting purposes, and for processing equipment to calculate the total quantity of energy consumed per ton of material processed. Default data on the energy required to produce a unit of electricity, including its precombustion energy, are included in the electrical energy process model documentation.

Air Emissions

The MRF process model accounts for airborne releases from two sources: (1) the pollutants released when fuel is combusted in a vehicle (combustion releases), and (2) the pollutants emitted when the fuel or electricity was produced (precombustion releases). Data for fuel and electricity production are included in the electrical energy process model documentation.

Water Releases

The MRF process model accounts for waterborne pollutant emissions associated production of energy (electricity and fuel) consumed at the MRF. There are no process related water releases. Default values for water releases from energy production are provided in the Electrical Energy process model documentation.

Solid Waste Releases

The MRF process model uses the energy consumed by equipment and for heating and lighting the MRF building to calculate the solid waste generated. Solid waste generation is expressed in terms of pounds of pollutant per ton of material processed. Note that the solid waste referred to in this section pertains to the waste generated from energy production processes. Default values for solid wastes generated due to energy production are provided in the Electrical Energy process model. Solid waste remaining after recyclables are removed (residue) is routed to a treatment or disposal facility. The LCI of residue is accounted for in these treatment and disposal facilities.

3.4 COMPOSTING

The composting process model includes both mixed municipal and yard waste composting operations. Composting using the windrow turner method is used for both types of facilities, instead of aerated static pile designs and in-vessel systems. The windrow turner design was selected because it is used by a majority of compost facilities in the United States.

Conceptual Designs for Composting

The three composting facility designs included in the system are summarized as follows:

COMP 1: MSW compost facility, low quality compost. Processes mixed MSW is collected and preprocessed at a MRF to remove any recyclable or non-compostable materials. This facility produces low quality compost that is used for landfill cover or is landfilled.

COMP 2: MSW compost facility, high quality compost. Processes mixed MSW is collected and preprocessed at a MRF to remove any recyclable or non-compostable materials. This facility produces high quality that is used for soil amendment.

COMP 3: Yard waste compost facility. Processes yard wastes (e.g., branches, grass, leaves) is collected and delivered to the compost facility by residents or a yard waste transfer station. Only one type of yard waste facility is designed; it is the same general design as the high quality MSW compost facility design.

In the general compost facility design, waste is collected at curbside and transported to a MRF where recyclables and non-compostable materials are removed. The residual mixed waste is transported to a compost facility. At the compost facility, waste is deposited onto a tipping floor, where large items (if any) are removed manually. A front-end loader introduces the waste to a preprocessing trommel screen. The finer fraction is directed to the composting pad or hammermill for shredding and then to the composting pad. The oversized fraction is sent to a landfill for disposal. Moisture is added to the compost to achieve an optimal moisture content. Turning, mixing, and aeration of the windrows takes place once or twice a week (a user input value) using self-propelled windrow turner. Curing takes place without any turning of the curing piles in an uncovered area, while cured compost is distributed for use as cover or sold as soil amendment. The compost facility is designed to handle MSW tonnage rates from 10 to 10,000 tons per day.

Note that there are some minor differences in the process flows of the different compost facility designs depending on the type of material being processed and desired quality of the final product. Refer to Appendix H for complete documentation describing the alternative compost facility designs.

Cost Methodology for Composting

The cost of a compost facility depends on the type of facility, the quantity and type of material processed, and user input data. Costs are divided into capital costs, O&M costs, and revenue from the sale of compost.

Capital Cost

The capital cost component for composting consists of construction, land acquisition, engineering, and equipment cost that can be expressed in annual terms using a given capital recovery factor that is dependent upon a book lifetime and discount rate.

- Construction cost includes the cost of the structure, access roads, fencing, landscaping, etc. The cost of the structure includes support facilities such as office space, a weigh station, and the loading conveyer. Construction cost is obtained by multiplying the floor area of the compost facility by the construction cost rate. Total area for the facility includes area for the structure, access roads, fencing, weigh station, landscaping, etc. Total area multiplied by a cost rate gives the land acquisition cost.
- Engineering cost consists of fees paid for consulting and technical services for the compost facility planning and construction, and is estimated to be a fraction of the construction cost.
- Equipment cost consists of the capital and installation cost of equipment.

Operating and Maintenance Cost

The O&M cost for the compost facility includes wages, overhead, equipment and building maintenance, and utilities.

- Labor required for the compost facility consists of management, drivers and equipment operators. In estimating the labor wages, it is assumed that part-time services can be hired. Management includes managers, supervisors, and secretaries. The wages paid for management are assumed to be a fraction of the wages paid to drivers and equipment operators.
- Overhead costs for labor are calculated as a fraction of labor wages. Overhead includes overtime, office supplies, insurance, social security, vacation, sick leave, and other services.
- The cost of utilities, assumed to be electricity, fuel, oil, etc., is assumed to be proportional to the weight of incoming MSW or yard waste.
- The cost of maintenance of equipment and structure is assumed to be proportional to the weight of incoming MSW or yard waste.

High quality compost that is produced by the high quality MSW compost facility or yard waste compost facility may be sold as soil amendment and thus provide revenue to help offset the costs of the compost facility. The user can enter the value of compost.

LCI Methodology for Composting

The LCI methodology calculates energy consumption or production, and environmental releases from the compost facility and allocates these LCI parameters to individual components of the waste stream.

Energy

The composting process model accounts for two types of energy consumption: fuel and electricity. The energy calculations include:

1. Combustion energy: the energy used in rolling stock, lighting and heating, and equipment, and
2. Precombustion energy: the energy required to manufacture the fuel or electricity from feed stock.

For electricity, the source of energy depends on the regional energy grid used. Default data on the energy required to produce a unit of electricity, including its precombustion energy, are included in the electric energy process model documentation. The composting process model uses default or user-supplied data on fuel consumed by rolling stock, for heating and lighting purposes, and for processing equipment to calculate the total quantity of energy consumed per ton of material processed.

Air Emissions

The composting process model accounts for airborne releases from two sources: (1) the pollutants released when fuel is combusted in a vehicle (combustion releases), and (2) the pollutants emitted from the biodegradation of organic material. Data for fuel production and electricity generation, and associated air emissions, are included in the common process model. Data for air emissions resulting from the biodegradation of organic material are being developed through a laboratory experiment being conducted at the University of Wisconsin-Madison. In this experiment, food, mixed paper, yard waste, and inorganics are biodegraded in lab-scale vessels. Emissions from the vessels are captured and analyzed and will ultimately be used to develop air emission factors for all waste components.

Water Releases

The compost process model accounts for waterborne pollutants associated production of energy (electricity and fuel) consumed at the compost facility. There are no process related water releases. Default values for water releases from energy production are provided in the common process model.

Solid Waste Releases

The compost process model uses the fuel consumed and energy consumed by equipment and for heating and lighting the compost facility to calculate the solid waste generated. Solid waste generation is expressed in terms of pounds of pollutant per ton of material processed. Note that the solid waste referred to in this section pertains to the waste generated when energy is produced. Default values for solid wastes generated due to energy production are provided in the common process model. Solid waste remaining after non-compostables are removed

(residue) is routed to a treatment or disposal facility. The LCI of residue is accounted for in these treatment and disposal facilities.

3.5 COMBUSTION

The MSW combustion process model includes sets of equations that utilize default (or user input) facility design information to calculate cost and LCI coefficients for combusting waste components in either an existing or new combustion facility, and with or without electrical energy recovery. These coefficients are used in the decision support tool to calculate the total system cost and environmental burdens for solid waste management alternatives that involve combustion.

Conceptual Designs for Combustion

The user of the decision support tool can choose whether the combustion facility to be included in the system is an existing facility or would have to be constructed. Default cost estimates for a new combustion facility are provided and are based on four basic designs of varying capacities. All designs assume that the facility will be operated to maintain compliance with all applicable regulations. Based on forecasts of the industry, combustion facilities of smaller capacities are assumed to be of modular design. Larger facilities are assumed to be of mass burn/waterwall design. Energy recovery is included for all designs.

Cost assumptions for the four designs are based on a 1989 study to estimate the cost implications for proposed emission standards [1]. The four design options include:

COMB1: Modular/starved air facility with a 100-ton-per-day (TPD) capacity.

COMB2: Modular/excess air facility with a 240 TPD capacity.

COMB3: Mass burn/waterwall facility with a 800 TPD capacity.

COMB4: Mass burn/waterwall facility with a 2,250 TPD capacity.

The conceptual design of these four facilities is similar. For the larger mass burn combustors (800, 2250 TPD), unprocessed waste (after removal of large, bulky items) is delivered by an overhead crane from a tipping floor to a feed hopper that conveys the waste into a combustion chamber. Hydraulic rams push the refuse from the fuel chute onto the first of several grates. The first section, or drying grate, is intended to remove the moisture content of the waste prior to ignition. The second section, or burning grate, is where the majority of active burning takes place. The third grate is where remaining combustibles in the waste are burned. Bottom ash is discharged from the finishing grate into a water-filled ash quench pit or ram discharger. From there, the moist ash is discharged to a conveyor system and transported to an ash load-out area prior to disposal. Water-filled tubes located in the walls of the combustor recover the waste heat that is used to generate electricity.

Combustion air is added from beneath the grate by way of under-fire air plenums. Typically, mass burn waterwall combustors are operated with 80 to 100 percent excess air. The flue gas exits the combustor and passes through additional heat recovery sections to one or more air pollution control devices.

The air pollution control equipment assumed to be present in a modern combustion facility includes a spray dryer for acid gas control, injection of activated carbon for mercury control, ammonia or urea injection for NO_x control (by conventional selective noncatalytic reduction), and a fabric filter for PM control. After the air pollution control equipment, the flue gas is released to the atmosphere through the plant stack. The fly ash is collected, mixed with the bottom ash, and sent to a landfill. In addition, air pollution monitoring equipment is installed in the facility.

The basic design of a modular-starved air combustor includes two separate combustion chambers, referred to as the "primary" and "secondary" chambers. Waste is batch-fed to the primary chamber by a hydraulically activated ram. Waste moves through the primary chamber slowly and retention times are long, lasting up to 12 hours. Auxiliary fuels may be added during startup or if there are problems. Air is supplied to the primary chamber at substoichiometric levels, resulting in a flue gas rich in unburned hydrocarbons. Air is mixed with the hot flue gas before entering the second combustion chamber to complete the burning. Energy is recovered in a waste heat boiler. The flue gas then passes through air pollution control equipment that is assumed to include the same processes described above.

Modular excess air combustors are similar to modular-starved air combustors except that the air is supplied in excess of stoichiometric requirements, and a portion of the flue gas is recirculated to maintain desired temperatures in the primary and secondary chambers.

Cost Methodology for Combustion

The methodology used to estimate the costs associated with combustion options are described in the following sections. Default values for new combustion facilities are based on a regression of the four model plants described above. The regression was performed to derive linear cost functions. Therefore the cost of the combustion facility is assumed to be proportional to the facility capacity, though the revenue from energy recovery is a function of the Btu input to the plant. Costs associated with combustion include capital costs, operation and maintenance costs, residue disposal costs, ferrous recovery revenue, and electricity generation revenue.

Capital Cost

The plant's capital cost includes the cost of combustors, ash handling system, turbine, and air pollution control and monitoring devices. The capital cost of a combustion facility is calculated from a unit capital cost with units of dollars per Btu/yr. feed rate. It is adjusted with a capacity factor because the plant cannot operate at full capacity at all times. In addition, it can be expressed in annual terms using a given capital recovery factor that is dependent upon a book lifetime and discount rate.

Operation and Maintenance Cost

The operation and maintenance (O&M) costs of a combustion facility include labor, overhead, taxes, administration, insurance, indirect costs, auxiliary fuel cost, electricity cost, and maintenance. The O&M cost function depends upon the unit O&M cost, the rate at which waste enters the plant (expressed in energy per unit time), the capacity factor, and the cost of ash disposal.

Combustion Residue Disposal Cost

Combustion residue includes residue from flue-gas cleaning and combustion ash (including fly and bottom ash). An assumption is made that the combustion residue is disposed of at an ash landfill and the cost for combustion residue disposal is not calculated and reported as part of the combustion process model but rather as part of the ash landfill model (see Section 8).

Revenue from Electricity Generation

Electricity that is generated by recovery of heat from combustion of waste is sold to an end user. The recovery of the heat is not perfectly efficient. This inefficiency is represented by the heat rate of the plant that is an input parameter. The default value for revenue from electricity generation is set at the national average of per kWh.

Revenue from Recovery of Ferrous Metal

Ferrous metal can be recovered from the bottom ash and can provide some revenue to help offset the costs of the combustion facility. Based on calculations shown in the combustion process model documentation, the cost of a magnet to separate the iron from the bottom ash is sufficiently small in comparison to the imprecise estimate of the ferrous scrap price that it can be ignored. The default value for revenue from scrap is based on the national market price for ferrous scrap.

LCI Methodology for Combustion

The LCI methodology calculates energy consumption or production, and environmental releases (air, water, and solid waste) from the combustion process and allocates these LCI parameters to individual components of the waste stream.

Energy

Energy recovered by the combustion facility is credited as an energy gain in the LCI inventory, and it is assumed to displace a similar amount of electricity produced from conventional fuels (e.g., coal and natural gas). However, the exact mix of the energy that is offset can be specified by the user if it is known.

Air Emissions

Net emissions from the combustion facility are the post-treatment emissions from the combustion facility minus the emissions that would have otherwise been produced by the type of utility generation being displaced.

Different sets of default emission factors for combustion of MSW are provided in the process model. Included are sets of defaults based on existing combustors in compliance with standards for existing facilities. We encourage the users to override these values with values based on the existing facility because there is considerable variation among individual combustors. In addition, defaults with emissions corresponding to the regulatory limits for existing combustion facilities may be selected. Similarly, for new facilities, defaults are provided based on actual performance of new facilities and a different set corresponding to the regulatory limits for new combustion facilities. For unregulated pollutants, defaults based on actual performance are provided.

Although emissions may be based on performance or regulatory limits, the composition of the waste still impacts emission levels. For example, while a pollutant may be controlled to a particular emission concentration, the volume of flue gas produced from the combustion of the waste components will dictate the mass emission rates of the pollutants. Since flue-gas production per ton varies considerably from component to component, the mass emission rates per ton of aggregate waste will vary with composition based on this methodology. Metals content by waste component and the partitioning of metals to the flue gas as observed in the Burnaby study [2] is used in conjunction with metals removal efficiencies based on multiple modern combustion facilities to form the basis for the calculations of mass metals emission rates. For lack of sufficient theory and empirical studies relating metals volatilization to waste composition, an underlying, albeit crude, assumption is made that metals emissions vary in proportion to metals input to the combustor. This approach was deemed to be preferable to the simpler approach that would have metals emissions vary with mass input alone with no sensitivity to the metals content of the waste.

Water Releases

Water releases associated with the combustion process are post-treatment releases from publicly operated treatment works of water used in the process and of water offset by generation of electricity. Net releases from the combustion facility are the releases from water use in the combustion facility minus the releases that would otherwise have been produced by the type of utility generation displaced.

Solid Waste Releases

Solid wastes from the combustion process include the solid wastes offset by generation of electricity. Ash residue is transported to a dedicated ash landfill for disposal.

3.6 RDF AND PRF

The objective of the Refuse Derived Fuel (RDF) and Processed Refuse Fuel (PRF) model is to calculate the cost and life-cycle inventory (LCI) parameters for converting MSW into fuel that is combusted in on-site combustors. The user can choose to use either the PRF design or the RDF design in the design of their integrated solid waste management system. Costs and LCI parameters are calculated on the basis of user input and default design information. Based on the cost and LCI design information, coefficients are calculated in the process model to represent

the cost and environmental burdens associated with a PRF or RDF facility. The coefficients take into account both the quantity and composition of the waste input to a PRF and RDF facility and are used in the solid waste management model to calculate the total system cost and LCI parameters for solid waste management alternatives that involve the PRF and RDF processes.

The mathematical equations used for model development are presented in the WTE document. Mass balance equations used to estimate the quantity and composition waste moving through the PRF or RDF process designs are presented in this document. The cost and LCI allocation methodologies are identical to the WTE process model, and are not presented in this document.

Conceptual Designs for RDF and PRF

Two designs for fuel processed from mixed waste are presented in this document. The differences between the PRF and RDF lie in steps in the process flow design preceding combustion of fuel. The following sections present descriptions of the processes involved in a Processed Refuse Fuel facility and a Refuse Derived Fuel facility.

Processed Refuse Fuel Facility

Figure 1 shows the steps in the process flow of the PRF facility. MSW is conveyed directly into a shredder to provide a maximum particle size of 6 inches, with most of the materials being less than 2 inches in size. The shredded material is then passed under a magnet for removal of approximately 40% to 50% of the ferrous metal. The remaining shredded material now termed PRF, is blown into specifically designed boilers at a point approximately 2 meters above a traveling grate. Lighter materials burn in midair while heavier portions of the fuel including non-combustibles, drop to the rear of the grate. The grate moves from the back to the front of the furnace to allow for complete burnout of any combustible material at an ash bed depth of 12-20 centimeters. The heat liberated by the combustion of the PRF is recovered to produce superheated steam for the generation of electricity. By forcing most of the combustion air through the grate, grate temperatures are maintained below the melting point of glass and most metals, thereby eliminating slagging and producing a granular bottom ash from which marketable materials can be recovered. From the bottom ash, a substitute for natural aggregate can also be produced. Bottom ash and fly ash are collected separately in a dry state, allowing for recovery of ferrous and nonferrous metals and the production of aggregate from the bottom ash and isolation of the fly ash for conditioning and disposal by landfilling and for future beneficial reuse.

In the PRF process model design used in the DST, it is assumed that there is no revenue associated with the sale of building aggregate material or coins and other metals that may be recovered from the bottom ash. The combustion stoichiometry and emissions allocation are exactly the same as in the WTE process model. Refer to the WTE process model documentation for more information.

Refuse Derived Fuel Facility

In the RDF facility, refuse that is received either unconfined or in bags, is loaded onto a conveyor system and enters a flail mill. The flail mill opens any unopened bags and reduces the sizes of some of the breakable materials in the refuse. From the flail mill, the refuse passes under a magnet that recovers ferrous materials which are a source of revenue. The remainder then continues into a trommel for removal of material less than 2 inches in diameter. The trommel removes materials like broken glass, grit, sand, etc. From the trommel, the refuse is shredded in a shredder to reduce the size of components of the waste. The shredded waste then passes through an air classifier that separates the "lights," considered to have the high BTU content, from the "heavies," which have a relatively low BTU content. The "lights" then flow to an eddy current separator for aluminum removal. The material remaining after aluminum removal is combusted and the heat energy liberated is converted to electricity.

The combustion stoichiometry and emissions allocation in the RDF process model are exactly the same as in the combustion process model.

Cost Functions for RDF and PRF

Costs for the PRF and RDF facility designs are divided into six components: capital cost, operation and maintenance cost, revenue from electricity generation and revenue from ferrous recovery, and revenue from aluminum recovery. The cost equations for the PRF and RDF facilities are exactly the same as those in the combustion process model.

LCI Functions for RDF and PRF

The environmental equations for the PRF and RDF facility are exactly the same as for the combustion process model.

3.7 LANDFILLS

The objective of the landfill process model is to calculate the cost and life-cycle inventory (LCI) for the burial of one ton of municipal solid waste (MSW) or combustion ash in a landfill. The model is designed to calculate the cost and LCI for one ton of waste in consideration of user-input and default values for a traditional, enhanced bioreactor, and ash landfill and can also to specify whether the landfill includes liner, landfill gas collection, and leachate collection systems. The formats for the three types of landfills are similar and areas of divergence are addressed in the following section.

Conceptual Designs For Landfills

Three types of landfill designs are considered in the decision support tool:

LF1: Traditional landfill operated to minimize moisture infiltration.

LF2: Bioreactor landfill operated to enhance decomposition.

LF3: Ash landfill.

These landfills are primarily defined by their physical characteristics and by the waste that they receive. All landfills are designed and operated in compliance with RCRA Subtitle D regulations. Bioreactor landfills use leachate recycling to enhance waste decomposition, leachate stabilization, and gas production. Ash landfills accept MSW incinerator ash. All three landfill process models contain five different phases in the landfill lifecycle:

- **Operations:** considers fuel use and equipment emissions associated with landfill operation.
- **Closure:** considers fuel use and equipment emissions associated with landfill closure.
- **Post-closure:** This section details the post-closure phase of a modern MSW landfill including cover maintenance and monitoring.
- **Landfill Gas:** This section describes gas generation, treatment, and utilization.
- **Landfill Leachate:** This section describes leachate generation and treatment.

Contrary to other waste management options, which generally have instantaneous emissions, landfill emissions occur over time. The emissions associated with disposal of a ton of waste in a landfill are reported for one of three user selected time horizons beginning from when the waste is placed in the site:

- A **short-term time frame (20 years)** corresponding roughly to the landfill's period of active decomposition.
- An **intermediate-term time frame (100 years)** corresponding roughly to the life span of a given generation.
- A **long-term time frame (500 years)** corresponding to an indefinite time reference, at which point the emission of any given environmental flow will have likely reached its theoretical yield.

Emissions are estimated for one time horizon which the user selects.

Cost Methodology For Landfills

The methodology used to estimate the costs associated with the three landfill options are described in the following sections. Landfill costs fall into four main categories: initial construction, cell construction, operations, and closure. To calculate the cost for each of these categories, the size of the landfill is needed. In order to size the landfill, the waste flowing to the landfill must be known. However, the waste flow to the landfill is specified by the decision support tool solution. Thus, to use the landfill process model, the size is based on user input values for the facility life and daily waste flow. As input by the user, these parameters are used to provide a rough estimate of landfill size which is used to calculate costs.

Landfills represent a unique problem relative to other MSW management unit operations in that

all other operations have a useful life and assumed replacement cost equal to its original cost. The same assumption is made for replacing a landfill.

Initial Construction Cost

Included in the initial construction cost are land acquisition; site fencing; building and structures required to support operation of the landfill and for a flare required for landfill gas treatment; platform scales; site utilities installation; site access roads; monitoring wells; initial landscaping; leachate pump and storage (in accordance with 40CFR258.40); site suitability study, planning and licensing. A multiplier is applied to the overall initial construction cost to account for engineering costs. The total cost is then amortized over the operating period of the facility and normalized to the annual volume of waste received.

Cell Construction Cost

The section summarizes the costs applicable to the development and preparation of each individual cell of the landfill. Cell construction costs include site clearing and excavation; site berm construction; liner systems (if specified and in accordance with 40CFR258.40); leachate control materials for traditional and ash landfills; leachate collection and recirculation materials for bioreactor landfills; and any cell pre-operational costs (e.g., engineering design, hydrogeologic studies). The total cell construction cost is amortized over the operating period of the facility and normalized to the annual volume of waste received.

Operation and Maintenance Cost

The operation and maintenance (O&M) costs of a landfill include labor, equipment procurement, leachate treatment, daily cover overhead, taxes, administration, insurance, indirect costs, auxiliary fuel cost, utilities, and maintenance. The O&M cost function depends upon the unit O&M cost, the rate at which waste enters the landfill. There is no amortization of the annual operation and maintenance because they are annual, recurring costs.

Closure and Postclosure Cost

Closure costs for the landfill model include costs associated with the installation of the final landfill gas extraction system (in accordance with 40CFR258.23); final cover (can include soil, geotextile, sand, HDPE, and clay as specified by the user); cost of replacing final cover; and perpetual care. The total closure cost is amortized over the operating period of the facility and normalized to the annual volume of waste received.

Revenue from Landfill Gas

If a turbine, boiler, or internal combustion engine is used to treat landfill gas, it may result in a revenue stream for the landfill. Three gas collection periods are defined in the model. Within each of the gas collection periods, the user has five options for landfill gas treatment: vent, flare, turbine, direct use, and internal combustion engine.. The electricity that is generated is assumed to be sold to an end user. The default value for revenue from electricity generation is set at the national average per kWh. The yearly revenue generated during each landfill gas treatment period is converted to the present value and then annualized over the operating life of the landfill. The amortized revenues for each period are then summed to obtain the total revenue

from landfill gas treatment. This total revenue offsets the cost of landfill construction, operation, and closure.

LCI Methodology For Landfills

The LCI methodology calculates the net energy consumption and environmental releases (air, water, and solid waste) from the landfill construction, operation, closure and post closure and allocates these LCI parameters to individual components of the waste stream.

Energy

Energy is consumed during the operation, closure and post-closure phases of the landfill. Energy that is recovered is credited as an energy gain in the LCI inventory, and it is assumed to displace a similar amount of electricity produced from conventional fuels (e.g., coal and natural gas). However, the exact mix of the energy that is offset can be specified by the user if it is known. In addition, the user can specify whether or not energy is actually recovered.

Air Emissions

Air emissions are associated with equipment use during each phase of the landfill as well as with decomposition of the buried waste and emissions during leachate treatment. Where energy is recovered, some air emissions associated with electrical energy production from fossil fuel is avoided.

Water Releases

Water releases associated with the landfill are post-treatment releases from publicly operated treatment works (POTW) of leachate. Net releases from the landfill are the releases from the POTW plus uncontrolled leachate. If energy is recovered from the landfill, then water releases would net out the releases that would otherwise have been produced by the type of utility generation displaced.

Solid Waste Releases

Solid wastes from the landfill processes include the solid wastes associated with energy utilization, treatment of landfill leachate, and production of landfill materials. If energy is captured at the landfill, then total solid waste is calculated by netting out the solid waste that would have otherwise been produced by the type of utility generation being displaced.

3.8 ELECTRICAL ENERGY

The electric energy process model provides an accounting of the total energy consumption and emissions resulting from the generation and use of electric energy. Pre-combustion and combustion energy consumption and emissions on a per unit fuel basis are used in conjunction with unit efficiencies, transmission and distribution line losses, and electric generation fuel types to allocate energy consumption and emissions to the use of a kilo-watt hour (kWh). Emissions and energy consumption per kWh are calculated for the national grid fuel mix as well as for the nine major electrical generating regions in the United States (see Tables 2 and 3). The user may

input a site-specific fuel mix.

The user may also change the default values for fuel mix by region, power generation efficiency, and other defaults.

The electrical energy process model results are used by spreadsheet models for other unit operations to obtain the total energy consumption and emissions related to electric energy usage in those unit operations. For example, energy is consumed and emissions result for each kWh of electricity used to operate a baler in a MRF. For each kWh consumed, the electrical energy process model provides the total energy consumed and the resulting emissions (pre-combustion and combustion).

Conceptual Designs For Energy Conversion

The vast majority of electrical energy in the United States is derived from seven major sources: coal, natural gas, residual oil, distillate oil, uranium, hydroelectric and wood. Therefore, these seven major fuel types are addressed by the electric energy process model with provision for the model user to include one “other” fuel type. Key points associated with each of the major fuel types are as follows:

- **Coal:** Pre-combustion energy and emissions for coal are associated with surface and underground mining operations, size reduction, cleaning and transportation. Use of coal as a fuel consists of burning it in a boiler to produce steam that is then used to generate electricity or is used for other process operations.
- **Natural Gas:** Pre-combustion energy and emissions for natural gas are associated with oil well operations, pipeline pumping, transportation, and fugitive emissions from pumping and production facilities. Use of natural gas as a fuel consists of combusting it in several types of facilities including gas turbines and combined cycle units to produce steam that is then used to generate electricity or is used for other processes.
- **Residual and Distillate Oils:** Pre-combustion energy and emissions for residual and distillate oils are associated with oil well operations, refining (process and fugitive emissions), and transportation. Use of residual and distillate oils as fuels consists of combusting them in boilers to produce steam that is then used to generate electricity or is used for other process operations.
- **Nuclear:** Pre-combustion energy and emissions for nuclear fuel are associated with surface and underground mining operations, refining (process and fugitive emissions), and transportation. Use of nuclear fuel consists of reacting it in a nuclear reactor to produce steam that is then used to generate electricity.
- **Hydroelectric:** There are no pre-combustion energy and emissions associated

with hydroelectric power generation, as a default. Use of hydraulic fuel usually consists of damming a river and using the potential energy of the entrained water to generate electricity by passing it through a water turbine-generator.

- **Wood:** Since wood fuel is usually a by-product of other wood processing operations and is usually burned on site for self-generated electricity, there are no pre-combustion emissions associated with wood fuel, as a default. Use of wood as a fuel consists of combusting it in a boiler to produce steam that is then used to generate electricity or is used for other process operations.

Insignificant contributions are made by sources such as solar, wind, geothermal, and other emerging technologies.

To provide the appropriate emissions and energy usage values to the various model components, it was necessary to define fuel usage by type for national and regional grids. Table 3-1 shows the regional grid definitions that have been adopted. The geographic locations of these grids are defined in Table 3-2. These grid definitions were adopted since they represent the vast majority of the United States, the area to which the model will most likely be applied. However, a “user-defined” region has been included to allow the model user to define a region with unique characteristics not available in the Table 3-3 default regions.

Table 3-1. Electric Region Definitions

Control Area Name	Control Area Description
ECAR	East Central Area Reliability Coordination Agreement
ERCOT	Electric Reliability Council of Texas
MAAC	Mid-Atlantic Area Council
MAIN	Mid-America Interconnected Network
MAAP	Mid-Continent Area Power Pool
NPCC	Northeast Power Coordinating Council
SERC	Southeastern Electric reliability Council
SPP	Southwest Power Pool
WSCC	Western Systems Coordinating Council
User Defined	User Defined Electric Region

Table 3-2. Electric Region Locations

Control Area Name	Location
ECAR	Michigan, Indiana, Ohio, Kentucky, West Virginia
ERCOT	Texas
MAAC	Pennsylvania, New Jersey, Maryland, Delaware
MAIN	Illinois, Missouri (east) Wisconsin (excluding north west)
MAAP	North Dakota, South Dakota, Nebraska, Minnesota, Wisconsin (east)
NPCC	New York, Vermont, Connecticut, Maine, Rhode Island, New Hampshire
SERC	North Carolina, South Carolina, Georgia, Florida, Alabama, Tennessee, Mississippi
SPP	Kansas, Oklahoma, Arkansas, Louisiana, Mississippi (west) Missouri (west)
WSCC	Washington, Oregon, Colorado, California, Nevada, Montana, Idaho, Wyoming, Utah, Arizona, New Mexico

Cost Methodology for Electrical Energy

Cost for electrical energy generation is *not* included in the boundaries for cost analysis. The cost that waste management operations accrue for electricity consumption is accounted for in the individual waste management process models.

LCI Methodology for Electrical Energy

Wherever electricity is consumed in the waste management portion of the system, the cost for electricity accrues to the local government. However, environmental burdens associated with the production and consumption of that electricity affects society as a whole. Therefore, the global environmental burdens associated with electrical energy production (termed precombustion emissions) are considered in this research. This section summarizes the approach used to determine precombustion emissions for different locales.

Electric Generation Fuel Usage

The national generation weighted usage for each fuel type was calculated from North American Electric Reliability Council (NERC) regional databases submitted to the Energy Information Administration (EIA) for 1994. These databases include several thousand generating units from the nine NERC regions in the continental United States and represent the vast majority of the U.S. generating capacity. The regional generation weighted usage for each generating region and fuel type were also calculated using EIA data.

Total Fuel Emissions

Pre-combustion and combustion emissions generated per 1000 fuel units combusted (pounds of coal, cubic feet of natural gas, etc.) on a national and regional basis are included in the appendices of the electric energy process model documentation. The default emissions data for all regions have been set to the values for national generation since data for fuel-related emissions for each of the nine generating regions were not available.

Energy and Emissions Offsets

To account for the energy and emissions savings associated with utility generation that is not required as a result of generating electricity from combusting MSW, RDF, or gases recovered from landfill or anaerobic digestion, it is necessary for the model user to specify the type of utility generation that is being displaced. This would typically be the type of generating unit being constructed in the region by the utility. The majority of units currently being constructed are coal and natural gas fueled. However, the type of fuel that would be displaced depends on the regional base-loaded fuel mix. For example, oil units are often base-loaded in Northeast states. If a base-loaded MSW combustor with energy recovery came on line in the northeast, the utility might back down an expensive oil-fired unit. Therefore, the definition of displaced fuel types is user definable with the default being coal and natural gas.

The default values and calculation methodology discussed in the preceding sections have been implemented in the electrical energy portion of the overall LCI model to ensure that the LCI implications of electrical energy consumption in various unit processes are accounted for. The intent of this implementation is to provide the best available default information. It is also to provide a model that is responsive to macro-level user input values such as electric generating

region and generating efficiency by fuel type while allowing for user override of micro-level inputs such as emissions associated with coal combustion should region-specific data become available.

3.9 TRANSPORTATION

The transportation process model calculates the cost and LCI coefficients associated with the transport of materials between the various unit processes included in the decision support tool. Note that transportation is different and separate from waste collection. Collection and drop-off processes for MSW, yard waste, and recyclable materials are addressed in the collection process model. Costs and LCI coefficients for transportation are calculated on the basis of user input and default design information that is described in this section. The factors take into account the composition of MSW transported and are used in the overall system to calculate the total system cost and environmental burdens for solid waste management alternatives as part of the decision support tool solution.

Conceptual Designs For Transportation

Transportation modes included in the decision support tool are rail, heavy-duty diesel (tractor-trailers), light-duty diesel vehicles, and light-duty gasoline vehicles. The type of roadway transportation mode utilized between any two given nodes is site specific. However, typically tractor-trailers are utilized for long-distance hauling to economize on transportation costs, while light-duty vehicles are utilized for shorter distances and more frequent trips. Cost and LCI coefficients for transport of mixed MSW, fuel, and compost are calculated per ton of aggregate mass flow between nodes. In contrast, recyclable materials are often shipped separately and have item-specific densities. For example, loose glass has a density much greater than plastic. For this reason, item-specific cost and LCI factors are calculated for recyclable materials transport. Connections for which item-specific factors are determined for recyclable materials include transport from transfer stations to separation facilities and from separation facilities to remanufacturing facilities.

For each nodal connection, unique cost and LCI factors are calculated based on user input values pertaining to transportation modes and connections between facilities. The governing equations presented in this section fall into three categories:

1. Rail transport of mixed refuse.
2. Roadway transport of non-recyclable materials (e.g., mixed refuse, refuse recovered for fuel, and compost).
3. Roadway transportation of recyclable materials.

Cost Methodology For Transportation

Costs of mixed refuse rail transport, non-recyclable materials roadway transport, and recyclable

materials roadway transport are calculated based on the default rate charged for hauling MSW. Factors contributing to transport cost include fuel consumption, vehicles, vehicle maintenance, licensing, and taxes. Rail transportation costs also include fees for the use of existing local rail lines between a community and a landfill. The cost for spurs built to connect existing rail lines to a transfer station and rail lines within transfer station sites are included in transfer station cost factors. Costs associated with moving MSW from the landfill rail transfer stations to the working face of the landfill are accounted for in the transfer station process model.

Rail Transport of Mixed Refuse

Cost factors for rail transportation of mixed MSW are calculated on a per ton basis from the user input hauling rate in units of dollars per ton per mile and the distances between nodes.

Roadway Transport of Non-Recyclable Materials

Cost factors for roadway transportation of non-recyclable materials are calculated on a per ton basis from the user input hauling rate in units of dollars per mile, vehicle weight capacity, and the distances between nodes.

Roadway Transport of Recyclable Materials

Item-specific factors are determined for recyclable materials because their densities vary. To calculate weight-based factors, volume-based costs for each transportation connection between nodes are first calculated. Volume-based costs are divided by item-specific densities to give weight-based factors. Costs per ton are then calculated for each recyclable item.

LCI Methodology For Transportation

LCI coefficients in the transportation process model account for production and combustion of fuel utilized by transportation vehicles. If the user selects a two-way trip as input for roadway transport connections, then calculated factors will account for empty vehicles returning to the origin. The LCI methodology calculates energy consumption and environmental releases (air, water, and solid waste) from transportation activities and allocates these burdens to individual MSW components to derive LCI coefficients that are used in the decision support tool.

Energy

Transportation accounts for the consumption of two main types of energy: fuels consumed by mode of transportation and electricity consumed in the production of fuels. The energy calculations for the LCI include both combustion and precombustion energy consumption. Combustion energy is the fuel or electricity consumed to operate rolling stock, lighting and heating. Precombustion energy refers to the energy consumed to produce the fuel used by the transportation mode. The transportation process model uses default or user-supplied data on fuel consumed for rail haul and roadway transport to calculate the total quantity of energy consumed per ton of material processed. Default data on the energy required to produce a unit of electricity, including its precombustion energy, are included in the electrical energy process model documentation.

Air Emissions

The transportation process model accounts for airborne releases from two sources: (1) the pollutants released when fuel is combusted in a vehicle (combustion releases) and (2) the pollutants emitted when the fuel was produced. Default value for air emission resulting from fuel production are included in the Electrical Energy process model documentation.

Water Releases

The transportation process model accounts for waterborne pollutant emissions associated production of energy (fuel) consumed during transportation of recyclable materials and waste. There are no process related water releases. Default values for water releases from energy production are provided in the Electrical Energy process model documentation.

Solid Waste Releases

Solid waste releases from the transportation process model are from the production of fuel consumed by vehicles to transport materials. Solid waste generation is expressed in terms of pounds of pollutant per ton of material transported. Default values for solid wastes generated due to energy production are provided in the electrical energy process model.

3.10 REMANUFACTURING

In cases where a material is recovered from the MSW stream and recycled, the tool calculates the environmental benefit (or cost) associated with remanufacturing that material into a new product. This calculation is an “offset analysis” in which any reductions (or additions) in environmental burdens associated with the use of recycled materials in place of virgin materials are included in the overall LCI. This procedure is summarized below.

Conceptual Designs For Remanufacturing

In MSW management strategies where some portion of MSW is recycled, the recyclables will ultimately be delivered to a facility for remanufacturing. 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 recyclables to a remanufacturing facility. At this facility, additional energy and resources will be expended to convert the recyclables to a new product. The total amount of energy (or other life-cycle inventory parameter) required to recover the recyclable from the waste stream and convert it to a new product will be included in the inventory analysis. This energy is termed E_r . In addition, we must include the amount of energy required to produce a similar amount of product from virgin material; this energy is termed E_v . The net amount of energy (E_n) expended (or saved) to recycle a material will then be calculated as the difference between E_r and E_v ($E_n = E_r - E_v$.)

Although energy has been used here as an example, a similar calculation will be performed for all LCI parameters involved in the remanufacturing process. This calculation assumes a closed-loop for all recycling processes and that the products manufactured using recycled materials is indistinguishable from the same product manufactured with virgin materials. However, the

quality of recycled materials is lower than that of virgin materials and thus more of the recycled material may be required to make the equivalent amount of product. Two key user input for the remanufacturing process model include the following:

- **Recycled Material Input Ratio:** the quantity of recycled material required to manufacture a product of equivalent quality and performance as virgin material.
- **Substitution Ratio:** the quantity of recovered material required to displace a unit of virgin material.

Use of this analytical framework requires selection of an intermediate product for which it is possible to compare LCI parameters between the virgin and recycle processes. For example, we recognize that PET beverage bottles are not typically recycled into new PET beverage bottles. Thus, although the starting material for the remanufacturing process may be a used PET beverage bottle, the end product upon which the LCI is based may be a fiber. In this case, we would want to compare LCI parameters between the virgin and recycle processes for fiber production. We selected intermediate products (e.g., aluminum ingot, plastic pellet) where possible as the end point for comparing virgin and recycling processes.

Cost Methodology For Remanufacturing

The costs associated with remanufacturing any given material accrue to the private sector and not to the public sector waste management entity. Therefore, remanufacturing costs are not included in the tool.

LCI Methodology For Remanufacturing

The remanufacturing process model provides estimates of net energy usage and emissions estimates on a per ton basis for products produced using virgin and/or recycled materials. The approach that has been taken in the remanufacturing process model is “cradle to product” in which the LCI parameters are compared up to some point in each manufacturing process where a common product can be identified. For aluminum, this is the point at which aluminum ingots are produced. For newsprint and corrugated containers, this is the point at which newsprint and corrugated liner and medium are produced.

Beyond these common points in the manufacturing process, the LCI parameters for each product are assumed to be identical regardless of what product is ultimately manufactured. Therefore, downstream items such as staples for corrugated containers and emissions from transporting the product to the user are not included in the LCI since these items are assumed to be unchanged regardless of whether the product is made from predominately virgin or recycled resources. This distinction is important in that it captures the difference between recycled and virgin manufacturing processes and not the absolute environmental burden.

The remanufacturing process model includes parameters for the following categories:

- **Material resource energy:** the fuel used in manufacturing that is physically integrated into the product rather than used to produce steam or electricity. Examples of this type of fuel usage are the use of coal to produce coke, which is then used to produce aluminum, or the use of petroleum to produce plastics.
- **Combustion process energy:** the electricity consumed in producing the product and the energy associated with the amount of fuel combusted in the production process. An example of this type of fuel combustion is the use of coal in process boilers to produce process steam.
- **Pre-combustion process energy:** the energy consumed in mining and transportation steps required to produce fuels used in the manufacturing process. Examples of this type of energy are the use of energy to extract petroleum, transport it to a refinery, and produce natural gas that is combusted at a manufacturing facility for process steam.
- **Combustion transportation energy:** the energy consumed to transport the various intermediate products or materials to the next unit process in the system. This information is estimated by Franklin Associates, Ltd. using national average transportation distances and modes (truck, ocean freighter, etc.).
- **Pre-combustion transportation energy:** the energy consumed in mining and transportation steps required to produce fuels for transportation. Examples of this type of energy are the use of energy to extract petroleum, transport it to a refinery, and produce diesel fuel for truck, ocean freighters, locomotives, etc.
- **Manufacturing emissions:** the total air, water, and solid waste emissions associated with both the production process and transportation energy consumption. This includes emissions from process, transportation, and pre-combustion activities.
- **Manufacturing energy consumption:** the total energy consumed in the manufacturing process, including combustion and precombustion, as well as process and transportation related energy consumption.

At this stage of the project, the remanufacturing process model only covers aluminum, corrugated containers, glass, and newsprint. Data for the virgin and recycled systems was produced by Franklin Associates, Ltd. and Roy F. Weston using a combination of their in-house LCI databases and publicly available LCI data.

Section 4

Model Capabilities, Uses, and Limitations

The objective of this section is to present information on the capabilities and appropriate uses and limitations of the model. During the development of the DST, considerable effort was expended to make it user friendly so that model users could obtain information quickly. Although this is an advantage for the experienced user, it can be problematic for the novice who innocently enters limited data, accepts the large number of default values provided without some review, runs the model, obtains results and interprets these results out of context. Similar to Section 2 – System Definition – this Section is designed to provide sufficient background information for the model user to understand the appropriate uses and applications of the model and interpretation of the results.

The DST is a mathematical representation of a highly complex solid waste management system. Given the complexities of the solid waste management system, it must be recognized that no model can completely describe an actual system. By necessity, some simplifications are required. The first level of simplification is described in Chapter 2 – System Description. The system description notes for example, that MSW is divided into a finite number of components that includes the major components of MSW and the major recyclables. Nonetheless, there are hundreds if not thousands of components in MSW and they could not all be itemized in this model. A second example of the type of simplifications inherent in the model is the use of sectors. The DST can accommodate up to 2 residential, 2 multifamily and 10 commercial sectors. In reality, a solid waste management district may include many residential and multifamily sectors and more than 10 commercial sectors. While there is no one strategy that will address this limitation for all users, an example of how this limitation was addressed in one case study should illustrate the types of things that can be done to adopt a community's solid waste management system to the DST.

In a case study performed for Lucas County, Ohio, it was determined that the solid waste management system included about 28 separate residential sectors. These sectors included Toledo, which contained approximately 70% of the total population of the county-wide solid waste management district, and 27 smaller communities, each with its own collection contract. For the Lucas County case study, one residential sector in the DST was used to represent Toledo and a second was used to represent average or typical data for the 27 smaller communities aggregated as one. This is just one example of the need for some creative use of the DST in modeling existing solid waste management districts.

The model limitations described in this chapter are divided into sections on 1) general uses of the model and its limitations, 2) general assumptions for the process models and 3) other

assumptions and limitations.

4.1 GENERAL MODEL USES AND LIMITATIONS

The DST is a planning and screening tool and not a design tool that can be used to generate a number of potential solid waste management strategies.

The DST is a screening tool and not a design tool. It is designed to be used to evaluate the entire solid waste management system, particularly when there is the potential to redesign a substantial part of the system. The model will identify a solid waste management solution that is optimal for a user defined objective and user defined constraints.

A suggested use of the model is illustrated as follows. After specifying location-specific information and accepting or modifying process model inputs, the user may use the optimization capabilities of the model. For example, the user may run the model with the objective of identifying a solid waste management alternative that has the least cost (model objective) and meets a landfill diversion rate of 25% (a constraint). Based on this objective and constraint, the model will identify the least expensive solid waste management alternative in which 25% diversion can be accomplished. [Note that diversion can be defined by the user to include or exclude recycling, yard waste composting and waste-to-energy (WTE)]. Similarly, the model could be given an objective to identify the solid waste management alternative that minimizes NO_x emissions (objective) while not exceeding a total annualized cost of 25 million dollars (constraint).

Once an "optimal" solution is identified, the user is encouraged to use the modeling to generate alternatives (MGA) feature of the DST. Using this feature, the user can start with the optimal solution and then identify alternate solutions that are only marginally suboptimal and are different to the maximum extent possible. For example, the user may look at the least cost solution and have some concern about its political viability. Using the MGA feature, the user could then ask the DST to search for solutions that are no more than an allowable increase in cost, for example 10% more expensive than the least cost solution. The DST will then generate a solution that is different from the "optimal" solution but still attractive with respect to cost. Similarly, if the objective function is to minimize NO_x emissions, then the user can start with this "optimal" solution and, using the MGA feature, identify solutions that might lower the total waste management cost by allowing 15% (a user input value) higher NO_x emissions.

Note that the DST cannot simultaneously optimize for minimum values of two LCI parameters. Rather, tradeoffs associated with multiple objectives such as cost and NO_x emissions should be obtained by multiple runs of the model with the appropriate objective functions and constraints.

The DST should be used to identify multiple favorable solutions to a given problem. The user should then inspect the proposed solid waste management strategies to identify those that appear viable for a given community in consideration of factors that were not modeled. Such factors could include political and social considerations, or the divergence between the current solid

waste management system and that proposed by the model.

Once a series of potentially viable management alternatives is identified, designs and cost estimates for these alternatives should be developed in detailed engineering studies. Final decisions on the implementation of a solid waste management system should be based on the results of these more detailed studies and not on the model results alone. In this respect, the model is a screening tool that should be used to narrow down the focus of a detailed engineering study. The model is not a design tool that should be used as the basis for how many collection vehicles to order or the acres of land to purchase for a solid waste management facility.

There Is Uncertainty Associated with the Model Results

Model results should be interpreted in consideration of the fact that they are not 100% precise. Two alternatives with slightly different costs or emissions may not be significantly different. It is not possible to state that cost or LCI are within some percentage as the results represent the combination of thousands of individual parameters, many of which will vary from scenario to scenario. With this in mind, the model is best used to identify several potentially favorable alternatives for detailed analysis that may include assessments of the uncertainty. Note also that to the extent that the data are imperfect, the model may still generate alternatives in the appropriate rank order as imprecision will affect all unit operations equally in the system.

While uncertainty estimates of the outputs are not provided by the DST, the user is encouraged to perform sensitivity analyses on key variables. The DST has been structured to make it easy for the user to change user-defined inputs and can perform a sensitivity analysis by repeated runs of the model. For example, if the user knows that labor wage rates may vary by 20% over the next year, then the model can be run with different wage rates in that range. While the user may have a reasonable idea of variability in the economics of solid waste management systems, many users will have little familiarity with variability in the life-cycle data. Some data quality information on the life-cycle parameters can be obtained from the stand alone database and users may apply this in sensitivity analyses of the LCI parameters.

The DST is a Steady-State Model

The DST is strictly a steady-state model. This means that only one value for each model input parameter can be entered and the model solution assumes that this parameter remains constant with time over the planning horizon.

A community is likely to experience many changes over the useful life of a solid waste management system. Potential changes include increased population and community size, labor rate increases and volatility in the unit revenues for the sale of recyclables and recovered energy. The sensitivity of model results to these and other changes should be explored by the user by making multiple runs of the model with varying values for specific input parameters.

The revenue associated with recyclable sales is perhaps the most volatile input and warrants some further consideration. In the economic portion of the model, the net cost of a solid waste management program is the cost after the realization of income from the sale of recyclables. While accurate, in actuality, a contract for the collection and or separation of recyclables may be based on the costs for collection and separation, with some agreement to share the associated revenue. Thus, the cost calculated in the model, which is a net cost, may be lower than the cost of a contract that separates the collection and separation cost from the revenues from recyclables. From a business perspective, such separation may be essential given the volatility in recyclable prices.

The calculated LCI represents global emissions

The calculated value for each LCI parameter represents the total for the entire solid waste management system. While the amount of a given emission that can be attributed to a specific unit operation, such as collection, landfill or remanufacturing is presented, the amount of a given emission that is attributable to sources within and outside of a community is not available. In actuality, only a fraction of each emission can be attributed to local activities. Some notable examples are discussed here.

In the case of collection, there are emissions associated with the collection vehicle that are clearly local. However, there are also emissions associated with the production of the diesel used to fuel the collection vehicle (precombustion emissions) and these emissions occur at the sites of petroleum extraction and refining followed by its transport to the local community. Emissions reported by the DST will simply report the sum of emissions for a particular pollutant. In addition, electricity is consumed due to activities associated with the administrative office and maintenance activities for refuse collection. The emissions associated with this power generation occur over a wide area. As described in the electrical energy process model, the electrical energy in the power grid is produced from a number of fuels at a number of distinct production facilities. These facilities are almost certainly not all within the local community.

With respect to recyclable manufacturing, note that the LCI is calculated as the difference between the value of the LCI parameter for a virgin manufacturing process and that for a recycled material manufacturing process. In a case where the manufacturing location is different for the virgin and recycled processes, changes in emissions at the facility handling recycled materials and at the facility handling virgin materials will be different. For example, as the mass of a material that is recycled increases, emissions may increase at the facility handling recycled materials and decrease at the facility manufacturing virgin materials. Therefore, while the global emissions associated with a unit of material recycling may be negative, the local community emissions may be positive depending on the geographic location of the associated manufacturing facilities. Nonetheless, from a global perspective, all emissions are summed to present one emission value that may be negative if there is a savings attributable to the recycled material manufacturing process.

The model presents a LCI and not an impact assessment

LCA includes three stages including the inventory stage, in which all emissions are quantified, an impact assessment stage in which the environmental impacts of an emission are calculated, and an improvement assessment stage in which the inventory is studied to identify areas of a process where some improvement is possible. The DST represents only the first stage, that of a life-cycle inventory. Efforts have been made to present the data in a manner that will support environmental impact assessment as appropriate assessment tools become available. In considering the impact assessment stage, the discussion of local versus global emissions must be considered.

The solid waste management system that was modeled begins at curbside

The solid waste management system that was modeled is based on the management of waste set out at curbside or brought to drop off facilities for composting and yard waste. Activities associated with solid waste management that occur at the site of waste generation are not considered. Examples of such activities include backyard composting piles and rinsing recyclables prior to their collection or drop off.

Construction related LCI effects are not included.

A decision to exclude construction from the overall model was made during the system definition phase of this research. Estimates of the significance of construction have shown that for most waste management facilities, this assumption is appropriate. However, for landfills, the total energy consumption for construction were found to represent 25% and 2% of the total landfill LCI for scenarios without and with energy recovery, respectively. The parallel energy values for combustion without and with energy recovery were estimated to be 0.2 and 3.2%, respectively. To the extent that the model solution includes a traditional landfill, the overall LCI values will be low due to the exclusion of its construction.

The model only allows for one of each type of facility

The overall model that is embedded in the DST only allows for the presence of one of each type of solid waste management facility. For example, a large solid waste management district might have two landfills or two MRFs. However, the model would only allow for one of each facility. Of course, the model does allow for multiple types of the same type of facility. For example, the model allows for up to five different MRFs, three landfills (traditional, bioreactor, ash), yard waste and mixed waste composting, etc. This could lead to cost estimates that are somewhat higher than actual. For example, the optimal solution could include two MRFs, one receiving commingled recyclables and one receiving mixed refuse. If a solid waste district were to construct these two MRFs, then it is possible that they would be located at the same site and would share certain facilities such as a parking area, gatehouse, some rolling stock and personnel associated with marketing recyclables. The economies of scale associated with locating two facilities on one site are not accounted for in the model.

The model does not consider how cost savings associated with solid waste management

might be spent

Solid waste management may be provided as a public sector service financed through property taxes, through private subscription, or through some combination of the two. Funds not spent on solid waste management in the public sector may be returned to the taxpayers through a tax rate decrease, or used for other publicly funded programs. Similarly, cost savings associated with private subscription should result in individuals having more disposable income. This income, whether in the hands of the public sector or the private citizen, may result in spending money on something else. This alternative use of money will have its own LCI that is beyond the scope of the DST model.

The DST is not dynamic

The DST assumes that any facility can be replaced at the same cost, corrected for inflation, as the cost at which a facility can be built initially. Further, the model assumes that equipment and facilities are repeatedly replaced at the end of their useful life with equivalent units of equal value. The DST does not address issues such as a transition from an existing MSW management system to a new management strategy. In particular, the model is not designed to optimize integrated waste management in the short term given an existing landfill with little remaining capacity.

To explore the importance of changes in variables such as the revenue from a recyclable, the generation rate, a collection parameter associated with a city growing - the user is encouraged to play “what if” games by deliberately changing various input parameters to explore the significance of the change on the model solution and the values of the cost and LCI parameters. The tool is designed to make this easy.

Economic Modeling

The cost and price may differ. The process models calculate the cost of each solid waste management unit operation in units of \$/mass of a MSW component processed. These values are based on estimates of the cost for a particular unit operation and make no allowance for whether the unit operation is built and operated by the public or private sector. Where a part of the solid waste management system is built and/or operated by the private sector, the actual price (tipping fee) will likely be higher than the cost to account for a profit. Thus, the costs calculated in the model may not represent price.

Use of engineering economics. All economic modeling is performed using standard engineering economics. This means that the capital cost of a facility is amortized over the useful life of the facility at a user input interest rate. This annualized cost is combined with annual operating costs to estimate total costs. The economic model does not address issues of cash flow, taxes and the like.

Costs borne by the private sector. The total solid waste management system cost includes the

cost to manage all waste generated and managed within the 2 residential, 2 multifamily and 10 commercial sectors. Certain of these costs, specifically the cost to manage waste generated in the commercial sectors which are presumably privately owned may be borne by the private sector. To obtain estimates of total public sector cost, the costs borne by the private sector, as identified by the model user, can be subtracted out. The model results are presented to allow the user to make this type of calculation. Alternately, wastes generated in sectors for which disposal is paid by the private sector can be excluded from the model to obtain public sector costs. However, private sector waste should not be included in the model at zero cost as the model will not properly evaluate cost-effective solutions for the private sector waste at zero disposal cost.

Decommissioning costs are not included. The economic analysis does not include the cost to return a site to its initial condition at the end of the useful life of the facility. In the case of a landfill, the economic analysis does include the cost for site closure and post-closure monitoring and maintenance.

4.2 LIMITATIONS ASSOCIATED WITH THE PROCESS MODELS

Process models have been written to calculate the costs and LCI of each solid waste management unit operation in consideration of the quantity and composition of the waste processed. Separate process models are incorporated in the DST for collection, transfer stations, transportation, separation, composting, WTE, RDF, landfills (traditional, bioreactor, ash) and remanufacturing. An overview of each process model is presented in Section 3 and full descriptions of each unit operation model are available separately. Some general comments on the structure of the process models and their importance are presented in this section.

The overall model and the cost and LCI estimates are based on linear relationships.

The DST is a linear model. This is the feature that allows for the evaluation of large numbers of alternate solid waste management strategies quickly on a personal computer. Thus, all process model coefficients must be linear, meaning that coefficients must be of the form of \$/ton MSW-component or mass NO_x/ton MSW-component. The resulting limitation of the model is that economies of scale cannot be considered mathematically. Thus, it is quite possible that a model solution will specify a unit operation to process an unreasonably small quantity of waste. For example, the model solution could include a WTE facility to process 20 TPD. This might occur if the user included WTE in the definition of diversion and was attempting to minimize cost while still meeting a diversion objective. It could also occur if the user wanted to maximize energy recovery while imposing a cost constraint. In these scenarios, the "optimal" solution might include combustion of enough waste to meet the diversion or energy objective, and a landfill for the remainder of the waste, assuming the cost of a landfill is below that of a WTE facility. The user should inspect a model solution for obvious problems such as an unreasonably small facility. Should this occur, the user should rerun the model after constraining it to generate a management strategy without using the facility (WTE in this example) that was originally proposed or require the use of WTE at some minimum tonnage.

The process models were not designed for optimization of individual unit operations

The DST can identify optimal solid waste management strategies given an objective to optimize one of 9 LCI parameters. However, the model is not designed to identify the optimal designs of individual solid waste unit operations. For example, aluminum cans can be separated from a stream of commingled recyclables either manually or by use of an eddy current separator. The user must select the separation technology to be used. The process model will not identify one alternative as being favorable. Similarly in the collection process model, the model estimates average truck transportation costs, but it is not meant to identify the optimal routing strategy for waste collection.

Only one process is currently considered for each recyclable in the remanufacturing process model

As described in the system definition in Section 2, an offset analysis is used to account for the difference in the LCI associated with manufacturing processes for virgin and recycled products. The product manufactured from each recyclable is unique and was selected to facilitate use of an offset analysis. For example, old newsprint (ONP) is assumed to be converted to new newsprint but the actual printing process is not considered for either virgin or recycled material as it is the same for both. Similarly, recycled aluminum is converted back to ingot from which many products can be made.

In many cases, a recycled material can be used in a number of ways. For example, ONP can be converted to new newsprint, animal bedding, or cellulose insulation among other products. In this model, ONP was assumed to be converted to new newsprint and the offset analysis was conducted on that basis. To the extent that ONP is converted to another product, the offset analysis would change. It should also be noted that many fiber recyclables are exported prior to the remanufacturing step. For this model, the location of the remanufacturing step, even if it was in another country, was not considered.

The offset analysis assumes direct product substitution

The offset analysis used to analyze the remanufacturing of recyclable materials assumes that the production of a product from a recycled material replaces the same product manufactured from the virgin material. This may not always be true. One stakeholder presented an example where recycled HDPE was used in place of virgin LDPE, which would have a slightly different LCI than virgin HDPE.

Beneficial reuse of ash is not included in the combustion and RDF process models

Ash is produced from MSW during its combustion in either a combustion facility or RDF plant. The only management alternative available for such ash is burial in a landfill. The beneficial use of ash in construction materials is increasing, thus reducing the disposal of ash in a landfill. Thus, for a specific locality, the cost and environmental emissions associated with ash burial

may not be relevant. Emissions from an ash landfill are reported in the DST results output and can be subtracted from the total LCI if appropriate.

Landfill Life

While there exists a relationship between landfill diversion and landfill life, and hence, unit landfilling costs, this effect is minimal in the context of a high level screening tool. It is assumed that the landfill life is sufficiently long so that unit landfilling costs are minimized. That is, the discounted landfill replacement costs are insensitive to the assumed landfill life for a typical design life of a landfill.

4.3 ADDITIONAL CONSIDERATIONS

Limit the size of the problem modeled

The DST is large and complex. In many cases, the user may be able to obtain the information needed without allowing consideration of every available solid waste management unit alternative. If the user is certain that mixed waste composting will not be used in a community, then this alternative should be disabled prior to running the model. The elimination of individual collection, treatment and disposal alternatives from consideration will decrease the time required to run the model. Minimum computing system requirements are addressed in Section ? (this will have to be addressed more thoroughly once the DST is final and ready for distribution).

Chapter 5

Scenario Building Using the MSW DST

Prior to the use of the DST to analyze a community's solid waste management system, the purpose and goals of a case study should be determined. What are the issues the solid waste manager wants to address? What changes to the current system do the manager want to consider? Can the goals of the solid waste manager be met within the limitations of the DST? Is the DST an appropriate tool to address the solid waste management issues within the community?

The main goal of the DST is to evaluate solid waste management (SWM) alternative scenarios that meet cost and life cycle inventory (LCI) emission targets. Therefore, the DST is an appropriate tool for analysis of issues such as cost and life-cycle emissions, increases in recycling or composting, or the development of a new management alternative. Solid waste managers should be aware that the DST does not address issues such as construction and demolition waste, or municipal versus private sector issues. Refer to Chapter 4 for discussion of applications and limitations of the DST.

This chapter of the manual describes the steps necessary to complete a DST sample session from start to finish. Since this is your first walk-through with the system, the steps within it have been simplified for the new user. Many steps, however will include a reference and page number that will guide you to a more detailed explanation of the procedure. Within this chapter are the following sections:

- 5.1 *Starting the DST***
- 5.2 *Define System***
- 5.3 *Set Targets***
- 5.4 *Solve***
- 5.5 *Alternative Scenario Examples***

The components of the three main steps in running the DST -- define system, set targets, and solve -- are shown on the following pages.

To demonstrate the applications of the DST we have established a sample case study for Anytown, USA. The goal of this case study is to consider alternative solid waste management plans that minimize cost, energy and carbon dioxide equivalents. Figure 5-1 depicts the material flow of municipal solid waste (MSW) through the waste management system of Anytown, USA that will be modeled within this chapter.

1. - Define System

1 Sectors

- Residential
- Multi-family
- Commercial

2 Unit Processes

- Collection
 - R-Yardwaste
 - R-Mixed Waste
 - R-Commingled/Crew
 - R-Pre-Sorted
 - R-Commingled/MRF
 - R-Co-Collection-One
 - R-Co-Collection-Two
 - R-Residuals
 - R-Recyclable Drop-Off
 - R-Vacuum
 - R-Yardwaste Drop-Off
 - R-Wet/Dry/Recyclables
 - R-Wet/Dry
 - MF-Recyclable Drop-Off
 - MF-Mixed Waste
 - MF-Pre-Sorted
 - MF-Commingled
 - MF-Residuals
 - MF-Wet/Dry/Recyclable
 - MF-Wet/Dry
 - C-Pre-Sorted
 - D-Mixed Waste
 - C-Residuals
- Transfer
 - Mixed Waste transfer
 - Commingled transfer
 - Co-collection/One transfer
 - Co-collection/Three transfer
 - Pre-Sorted transfer
 - Rail transfer
 - Rail to D1
 - Rail to D3
- Separation
 - Mixed Waste MRF
 - Presorted MRF
 - Commingled MRF
 - Co-collection/One MRF
 - Co-Collection/Three MRF
 - Compost Frontend
- Treatment
 - Yardwaste Compost
 - Combustion
 - RDF
 - Mixed Waste Compost
- Disposal
 - Landfill
 - Ash Landfill
 - Wet Landfill

3 Cost/LCI

- Cost
- Energy Consumption
- Particulate Matter 10
- Total Particulate Matter
- Nitrogen Oxides
- Sulfur Oxides
- Carbon Monoxide
- Carbon Dioxide Biomass
- Carbon Dioxide Fossil
- Green House Equivalents

4 Define Diversion

- Recyclables
- Yardwaste Composting
- Combustion
- Mixed Waste Composting

5 Process Model Input

— Generation

- Generation Parameters
 - Residential
 - Multi-family
 - Commercial
- Composition
 - Residential
 - Multi-family
 - Commercial
- Waste Mixture Definitions
 - Paper
 - Plastic
 - Glass

— System-wide inputs

- MSW Properties
 - Heating Value
 - Combustion Residuals
- Economic Parameters
 - Interest Rates
 - Cost Indices
- LCI
 - Greenhouse Gas Equivalents

— Collection

- General
 - Density in collection vehicle
 - Garage/Office
- Recyclables
 - Residential
 - Non-sector specific data
 - Schedule & Operating times
 - Labor & Economic data
 - Bins
 - Vehicles
 - Operational
 - Compaction factors
 - Airborne release rates
 - Waterborne release rates
 - Sector-specific data
 - Schedule & operating times
 - Labor & Economic data
 - Vehicle
 - Cost & capacity
 - Participation factors
 - Capture rates
 - Cost/LCI coefficients
 - Multi-family
 - Schedule
 - Participation factors
 - Capture rates
 - Operation times
 - Vehicle
 - Misc
 - Density
 - Compaction factors
 - Bins
 - Cost/LCI Coefficients

Commercial
Same listing as
previous Multi-family

- Mixed Waste
 - Residential
 - Schedule
 - Operation times
 - Vehicle
 - Misc
 - Density
 - Compaction factors
 - Cost/LCI Coefficients
 - Multi-family
 - Same listing as
previous Residential
 - Commercial
 - Same listing as
previous Residential
- Co-Collection
 - Residential
 - Schedule
 - Operation times
 - Vehicle
 - Misc
 - Density
 - Cost/LCI Coefficients

- Wet / Dry
 - Residential
 - Separation
 - Schedule
 - Operation times
 - Vehicle
 - Misc
 - Density
 - Compaction factors
 - Bins
 - Multi-family
 - Same listing as
previous Residential
 - Commercial
 - Same listing as
previous Residential

- Yardwaste
 - Residential
 - Schedule
 - Operation times
 - Vehicle

- Dropoff
 - Schedule
 - Route
 - Vehicle
 - Misc
 - Density
 - Compaction factors

— Transfer

- Mixed waste transfer station
- Commingled transfer station
- Co-collection transfer station (1cmpt.)
- Co-collection transfer station (2cmpt.)
- Rail transfer station

— Separation

- Design options
 - Individual MRFs
 - Front End MRFs
- Working time
- Bag Misc.
- Capital costs
 - Cost rates
 - Data for area calculation
 - Equipment
 - Cost
 - Lifetime
 - Other
- O&M costs
 - Labor
 - Other
- Waste item specific
 - Sorting efficiency
 - Picker rate
 - Density in bin
 - Weight of a bale
 - Scrap market prices
- LCI
 - Rolling stock
 - Energy consumption

— Treatment

- Yard waste composting
- Mixed waste composting
- Waste-to-Energy
 - Economic
 - Nonmetal air pollutants
 - Stack emission factors
 - Metal air pollutants
 - Removal efficiency
 - Uncontrolled emissions
 - Waterborne
 - Other LCI
- RDF facility
- Backyard composting
- Anaerobic digestion

— Disposal

- Landfill
- Ash landfill
- Enhanced bioreactor

— Remanufactor

- Paper

— Electric Energy

- Emissions

2. - Set Targets

1 Cost / LCI

- Optimizable Parameter
 - Cost
 - Energy Consumption
 - Total Particulate Matter
 - Nitrogen Oxides
 - Sulfur Oxides
 - Carbon Monoxide
 - Carbon Dioxide Biomass
 - Carbon Dioxide Fossil
 - Green House Equivalents

2 Unit Process Flows

- Collection
 - R-Yardwaste
 - R-Mixed Waste
 - R-Commingled/Crew
 - R-Residuals
 - MF-Mixed Waste
 - MF-Pre-sorted
 - MF-Residuals
 - C-Pre-sorted
 - C-Mixed Waste
 - C-Residuals
- Separation
 - Pre-sorted MRF
 - Commingled MRF

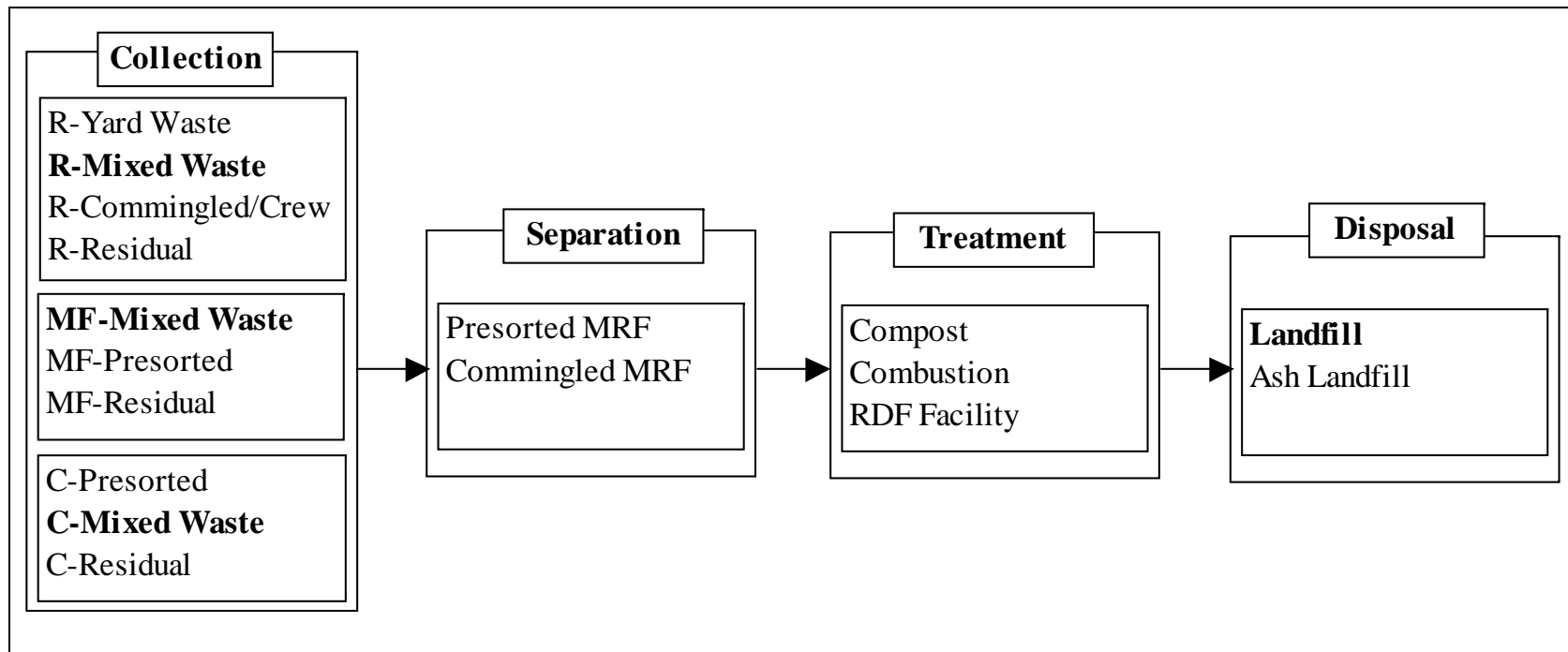
3 Diversion Rate

- All Sectors

3. - Solve

1 Run Optimizer

2 Strategy Name



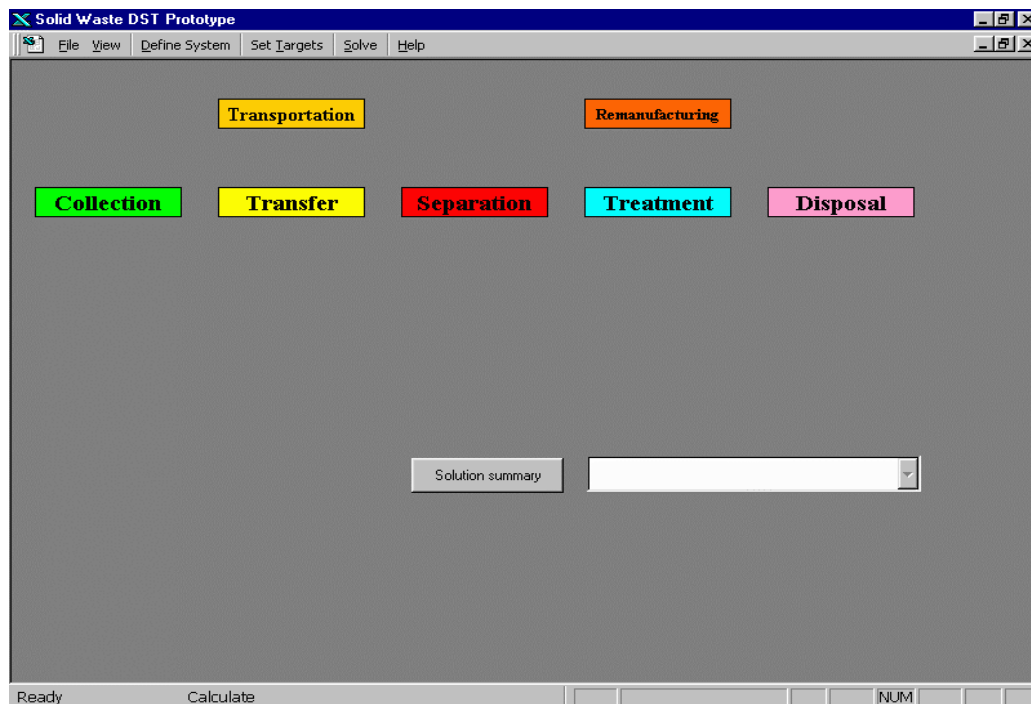
Where R=residential; MF = multi-family; C = commercial.
 Note that the unit processes in bold represent the baseline model.

Figure 5-1. Material Flow Through Anytown, USA.

5.1 STARTING THE DST

To start the DST, double click the DST icon on your desktop (see Chapter 1, Introduction).

- 1) At the Microsoft Excel screen, click the ***Enable Macros*** button.
- 2) At the next Microsoft Excel screen, click the ***NO*** button to not update links.
- 3) The DST main screen appears. Wait until the hour glass icon (indicates that the program is loading - this will take 2 to 3 minutes) turns into the **+** icon (indicates that the DST is ready to use) before proceeding to Step 1 below.



5.2 DEFINE SYSTEM

In this session, you will begin to develop the baseline operations for Anytown, USA. You do this by entering the SWM data into the Define System (see button on top command line above) submenu categories of Sectors, Unit Processes, Cost/LCI, Define Diversion, and Process Model Input. Each of the five steps within this section will refer to a different submenu category:

- Step 1: Define System - Sectors**
- Step 2: Define System - Unit Processes**
- Step 3: Define System - Cost/ LCI**
- Step 4: Define System - Define Diversion**
- Step 5: Define System - Process Model Input**

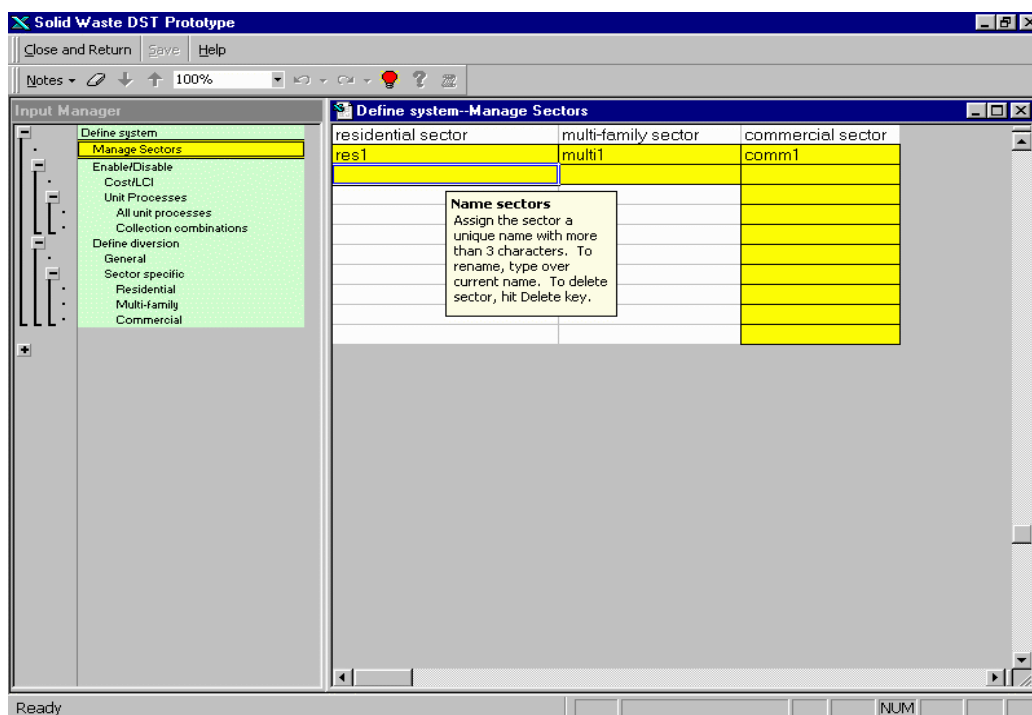
Each of these steps will contain directions and sample data that you will enter into system, as denoted by “**ACTION:** directions, *screen items*, and *sample data*.” Note that once the model is run, these parameters cannot be changed without having to rebuild the model.

Step 1. Define System - Sectors

This first step enables the user to build the baseline Sectors for Anytown, USA.

ACTION:

- At the command line at top of screen, click **Define System** button.
- Select **Sectors** from the pull down menu.
- The following screen appears.
- The left Input Manager window will be discussed in step 5.



The DST is equipped to model two residential, two multi-family, and ten commercial waste management sectors. There are three main waste management sectors in the sample community of Anytown, USA. This ability to model different sectors enables a community to distinguish between sectors of the community that have distinct waste generation rates, waste compositions, and collection methods. For example, the residential and multi-family sectors may be defined as urban and rural communities, while commercial sectors may be distinguished as retail stores, restaurants, hospitals, and other commercial establishments.

ACTION: Click in the appropriate yellow cell in the right window and enter a name for each sector (see above screen shot). If data already appears in cell, overwrite it.

- Click in yellow cell under residential sector, enter *res1*, and press Enter.
- Click in yellow cell under multi-family sector, enter *multi1*, and press Enter.
- Click in yellow cell under commercial sector, enter *comm1*, and press Enter.
- Click on the **Close and Return** button, in upper left corner, to return to the main screen.

Step 2. Define System - Unit Processes

ACTION:

- At the command line at top of screen, click **Define System** button.
- Then select **Unit Processes** from the pull down menu.
- The following screen appears.

Sector type	Short name	Can be Enabled	Enabled
Collection	R-Yardwaste	TRUE	TRUE
Collection	R-Mixed Waste	TRUE	TRUE
Collection	R-Commingle/Crew	TRUE	TRUE
Collection	R-Pre-Sorted	FALSE	FALSE
Collection	R-Commingle/MPF	FALSE	FALSE
Collection	R-Co-Collection-One	FALSE	FALSE
Collection	R-Co-Collection-Two	FALSE	FALSE
Collection	R-Residuals	TRUE	TRUE
Collection	R-Recyclable Drop-Off	FALSE	FALSE
Collection	R-Vacuum	FALSE	FALSE
Collection	R-Yardwaste Drop-Off	FALSE	FALSE
Collection	R-Wet/Dry/Recyclables	FALSE	FALSE
Collection	R-Wet/Dry	FALSE	FALSE

Now you must define the baseline unit processes of the SWM system of Anytown, USA. The DST includes the waste management process categories of collection, transfer, separation, treatment, and disposal as displayed in Figure 5-1 on page 1.

ACTION:

- Click the right window and scroll up and down to view the entire listing of the above screen.
- To enable each unit process type for the baseline, click in the yellow cell to its right and enter ***True***.
- Likewise, to disable a unit process type from evaluation, enter ***False***.
- Now click into right yellow cell next to each unit process type and enable/disable as listed in the following representative table. (Table 1)
- When complete, click on the ***Close and Return*** button to return to the main screen.

Table 5-1. Unit Processes in the DST.

COLLECTION	User Enabled
R-Yard Waste	TRUE
R-Mixed Waste	TRUE
R-Commingled/Crew	TRUE
R-Pre-Sorted	FALSE
R-Commingled/MRF	FALSE
R-Co-collection-One	FALSE
R-Co-collection-Two	FALSE
R-Residuals	TRUE
R-Recyclables Drop-off	FALSE
R-Vacuum	FALSE
R-Yard waste Drop-off	FALSE
R-Wet/Dry/Recyclables	FALSE
R-Wet/Dry	FALSE
MF-Recyclables Drop-off	FALSE
MF-Mixed Waste	TRUE
MF-Pre-sorted	TRUE
MF-Commingled	FALSE
MF-Residual	TRUE
MF-Wet/Dry/Recyclables	FALSE
MF-Wet/Dry	FALSE
C-Presorted	TRUE
C-Mixed Waste	TRUE
C-Residual	TRUE
TRANSFER	User Enabled
Mixed Waste Transfer	FALSE
Commingled Transfer	FALSE
Co-Collection/One Transfer	FALSE
Co-Collection/Three Transfer	FALSE
Presorted Transfer	FALSE
Rail Transfer	FALSE
Rail to D1	FALSE
Rail to D3	FALSE

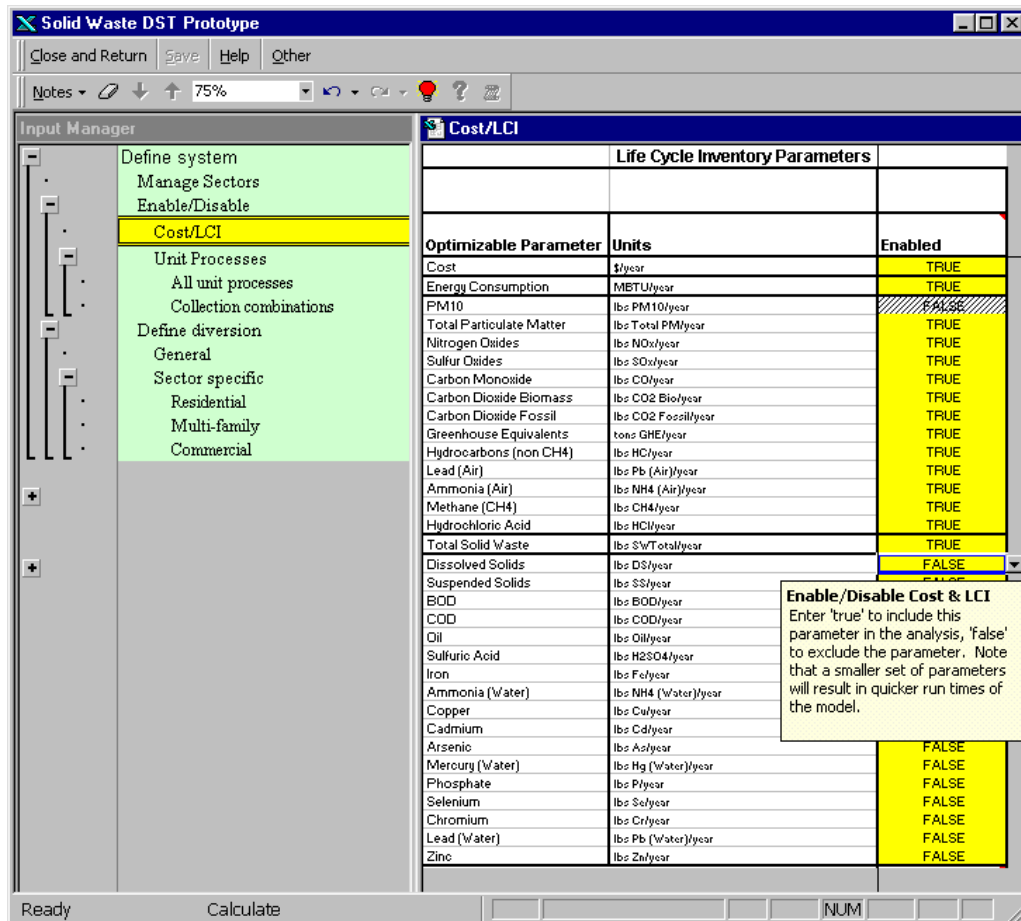
SEPARATION	
Mixed Waste MRF	FALSE
Presorted MRF	TRUE
Commingled MRF	FALSE
Co-Collection/One MRF	FALSE
Co-Collection/Three MRF	FALSE
Compost Front-end	FALSE
TREATMENT	
Yardwaste Compost	TRUE
Combustion	TRUE
RDF	TRUE
Mixed Waste Compost	FALSE
DISPOSAL	
Landfill	TRUE
Ash Landfill	TRUE
Wet Landfill	FALSE

Step 3. Define System - Cost/LCI

This category of the tool dictates the optimizable parameters that the model will calculate. Therefore, if a community is exclusively interested in cost and carbon dioxide equivalents, the model can be set to only consider these parameters. If you are interested in evaluating cost and LCI parameters, then all parameters may be selected.

ACTION:

- At the command line at top of screen, click *Define System* button.
- Then select *Cost/LCI* from the pull down menu.
- The following screen appears.
- Click in appropriate yellow cell in right window and enter all *True*, as appears in the screen shot below, for all optimizable parameters.
- Click on the *Close and Return* button to return to main screen.



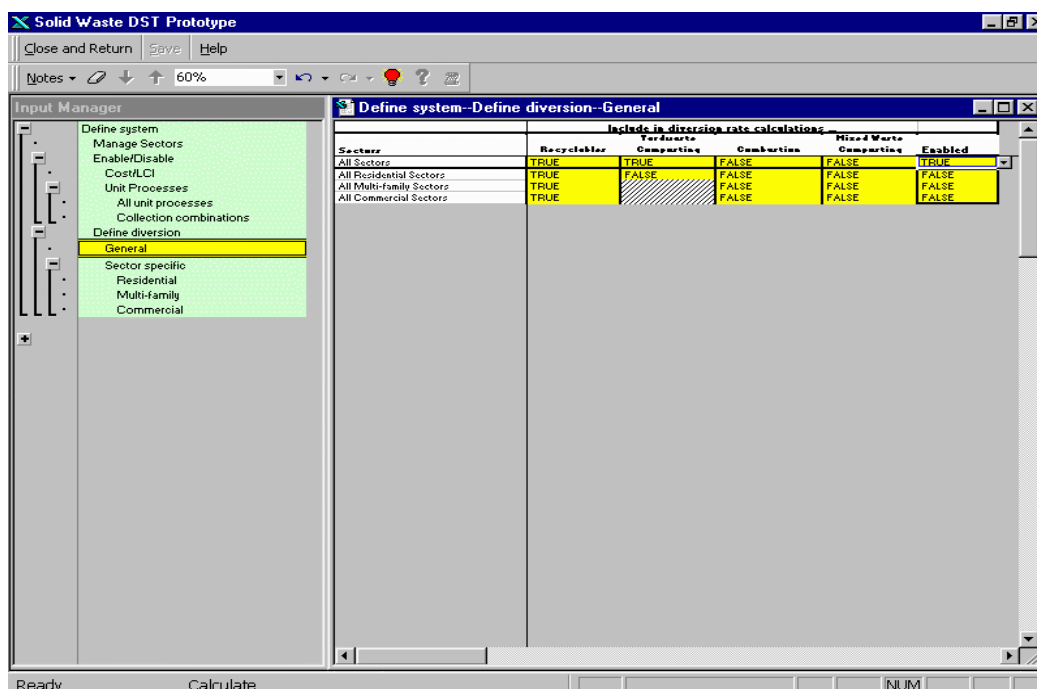
Step 4. Define System - Define Diversion

To provide a flexible model, the DST allows you to create your own definition of diversion. Diversion can include any waste that is not landfilled, such as waste that is recycled, composted, combusted, or processed at an RDF facility. You can define diversion according to the regulatory policies of the case study community.

For Anytown, USA the calculation of recycling diversion will include recycled and composted materials.

ACTION:

- At the command line at top of screen, click **Define System** button.
- Select **Define Diversion** from the pull down menu.
- The following screen appears.
- Click in appropriate yellow cells in right window and enter **True** and **False** as in the example screen below.
- Click on the **Close and Return** button to return to main screen.



Step 5. Define System - Process Model Input

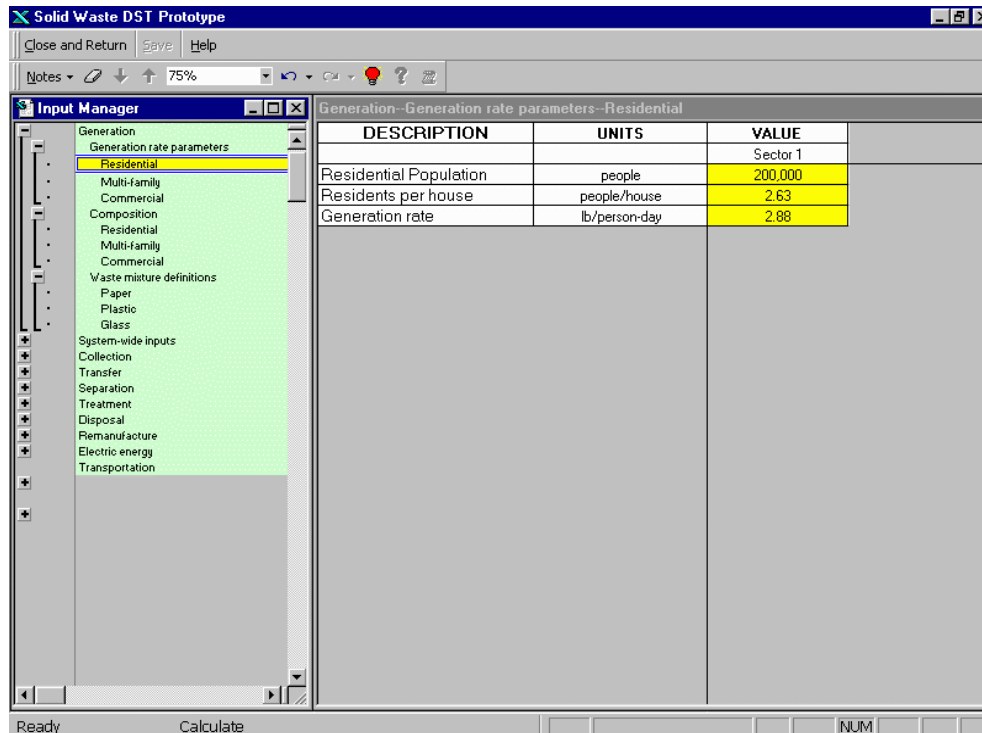
You now have the ability to accept or change the default values in the DST. To develop a community-specific model, it is necessary to input the waste generation rate and composition for the community.

Additional input data provided by a solid waste manager of a community will make the DST a more community-specific model. Examples of these data include collection frequency, travel distances between operations, and loading time per stop. If these data are not available, default data within the model will be used.

For the Anytown model we will input Generation, Composition, and Additional Data. In this step we will use both the right window and the Input Manager left window.

ACTION:

- At the command line at top of screen, click **Define System** button.
- Select **Process Model Input** from the pull down menu.
- The following screen appears.



The left window Input Manager screen, shown in the screen capture above, lists all of the necessary categories and sub-categories needed to tweak the built-in defaults of the system (i.e., Generation, System-wide inputs, and all the Unit Processes categories). Since the listing is in MS Windows hierarchical outline format, the main category headings will appear furthest to the left; the sub-category headings along with their listings are indented under the main category headings. The + icon tells you that there is additional information under a category heading and the - icon tells you that the category heading listing is already open. A single click on these icons will move you into (+) or away (-) from a category.

Step 5.1 Generation Data

For the single-family residential and multi-family sectors the generation rate is calculated in pounds per person per day (ppppd). Additionally, the population and the average number of residents per house should be determined for each sector. For the commercial sectors, the generation rate is in pounds per location per day. Also the number of commercial locations in each sector should be determined.

To input generation data within the DST, the input manager on the left side of the screen should be used. Generation data for Anytown, USA were developed by slightly modifying default data.

Residential Generation Data:

ACTION:

- In the left Input Manager screen, go to **Generation / Generation rate parameters / Residential**.
- If the **Generation** category is not already open, single click the + icon to the left of it to open its contents.
- Now single click on **Residential**.
- The above screen appears.
- Click on yellow cell to the right of **residential population (people)**. and enter **200,000**; press Enter.
- Click on yellow cell to the right of **Residents per house (people/house)** and enter **2.63**; press Enter.
- Click on yellow cell to the right of **Generation Rate (lb/person-day)** and enter **2.88**; press Enter.
- Click on the **Close and Return** button to return to main screen.

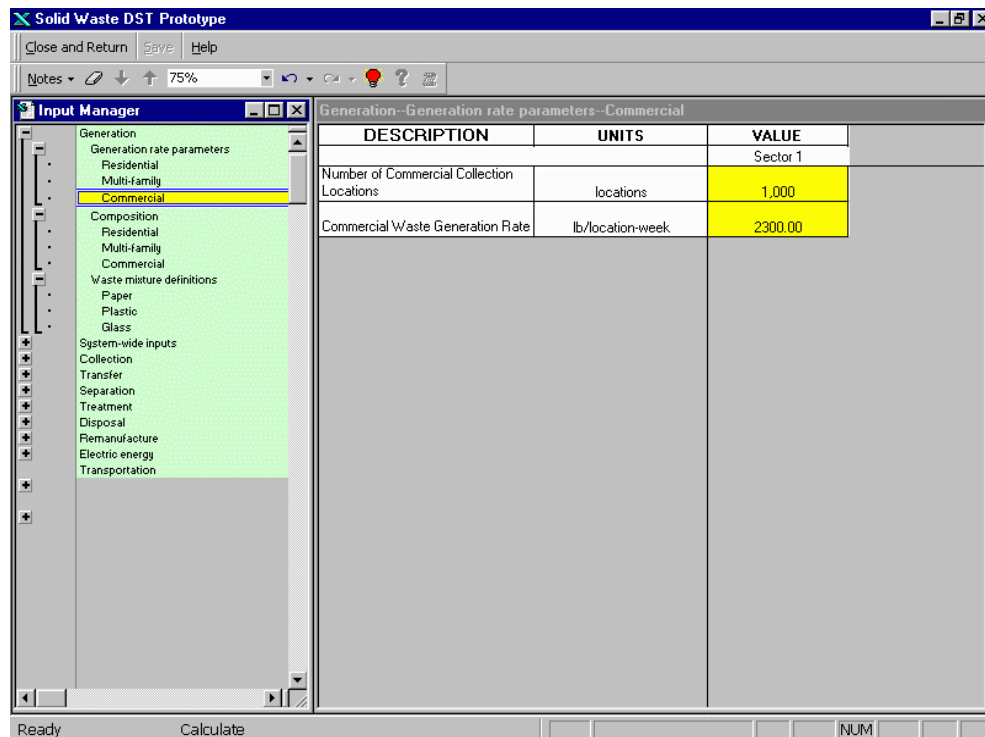
Multi-Family Generation Data:**ACTION:**

- In the left Input Manager screen, go to **Generation / Generation rate parameters / Multi-family**.
- If the **Generation** category is not already open, single click the + icon to the left of it to open its contents.
- Now single click on **Multi-family**.
- The following screen appears.
- Click on yellow cell to the right of **multi-family population (people)**. and enter **100,000**.

The screenshot shows the 'Solid Waste DST Prototype' application window. The 'Input Manager' pane on the left has 'Multi-family' selected under 'Generation rate parameters'. The main window displays a table titled 'Generation-Generation rate parameters-Multi-family' with the following data:

DESCRIPTION	UNITS	VALUE
		Sector 1
Multi-Family Population	people	100,000
Generation rate	lb/person-day	2.88
Number of Multi-family collection locations	locations	100

The status bar at the bottom shows 'Ready', 'Calculate', and 'NUM'.



Commer

cial Generation Data:

ACTION:

- In the left Input Manager screen, go to **Generation / Generation rate parameters / Commercial**.
- If the **Generation** category is not already open, single click the + icon to the left of it to open its contents.
- Now single click on **Commercial**.
- The following screen appears.
- Click on yellow cell to the right of **No. of collection locations (locations)**. and enter **1,000**; press Enter.
- Click on yellow cell to the right of **generation rate (lbs/location-week)** and enter **2,300**; press Enter.
- Click on the **Close and Return** button to return to main screen.

Step 5.2 Waste Composition

The waste composition is defined by the forty-eight waste constituents shown in Table 2. The shaded cells indicate waste constituents not available within that sector. Table 2 also contains waste composition values for Anytown, USA.

The waste constituents within the DST are defined by the following general categories. The first letter in the acronym stands for Residential, Multi-family, or Commercial sectors.

RTYL, MTYL = Yard Trimmings, Leaves

RTYO, MTYO = Yard Trimmings, Other

RCCR, MCCR, CCCR = Combustible, Compostable, Recyclable

RCNR, MCNR, CCNR = Combustible, Non-Compostable, Recyclable

RNNR, MNNR, CNNR = Non-Combustible, Non-Compostable, Recyclable

RCCN, MCCN, CCCN = Combustible, Compostable, Non-Recyclable

RCNN, MCNN, CCNN = Combustible, Non-Compostable, Non-Recyclable

RNNN, MNNN, CNNN = Non-Combustible, Non-Compostable, Non-Recyclable

The constituents of CCCR other, CCNR other, CNNR other, or any of the CCCN, CCNN, and CNNN categories are not considered for recycling in the DST.

The “other” categories, such as “paper other #1” are supplied for waste constituents that cannot be otherwise defined by the DST. Heating values and remanufacturing data must also be supplied for these categories.

The “mixed” categories are defined as a mixture of waste constituents. For example “mixed glass” may be defined as a mixture of brown, green, and clear glass.

National averages of waste composition are assumed for Anytown, USA, and are based on the

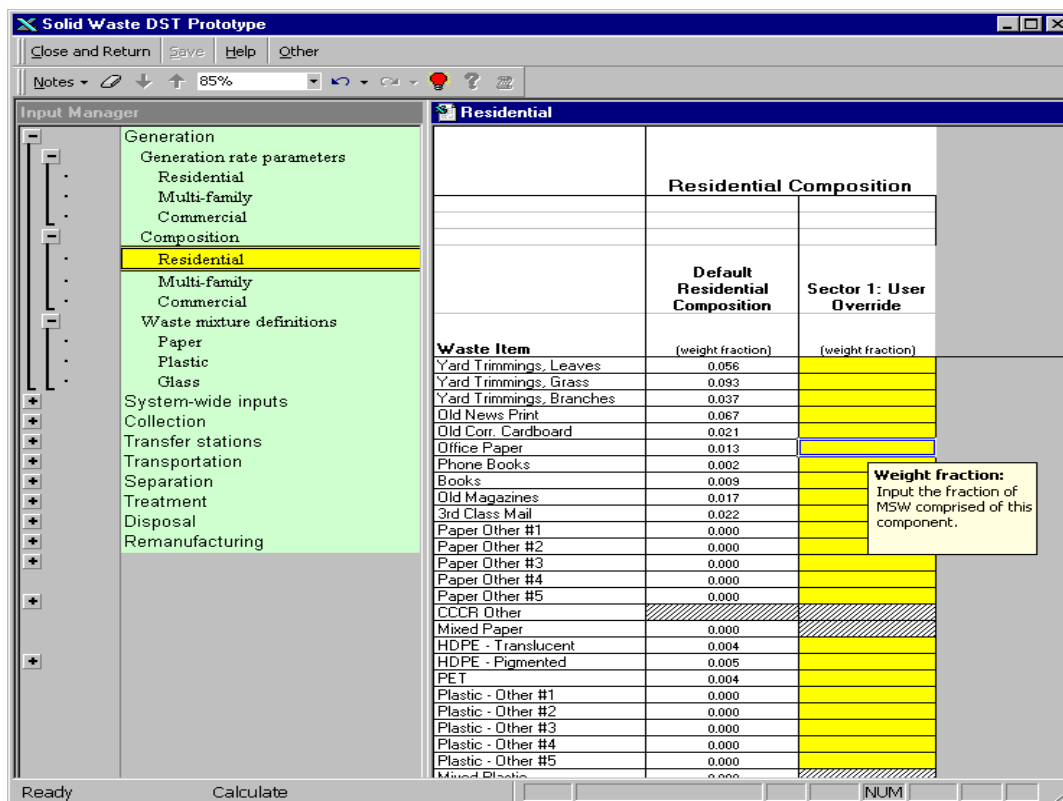
1994 Franklin Report (U.S. EPA, 1996). To enter them into the DST, the following steps are taken:

ACTION:

- In the left Input Manager screen, go to ***Composition / Residential***.
- If the ***Generation*** category is not already open, single click the + icon to the left of it to open its contents.
- Now single click on ***Residential***.
- The following screen appears.
- At this point we will accept the system default data and not modify the yellow input cells.
- These steps can be repeated to verify ***Multi-family*** and ***Commercial*** default composition.
- Click on the ***Close and Return*** button to return to main screen.

Table 5-2. Waste Constituents

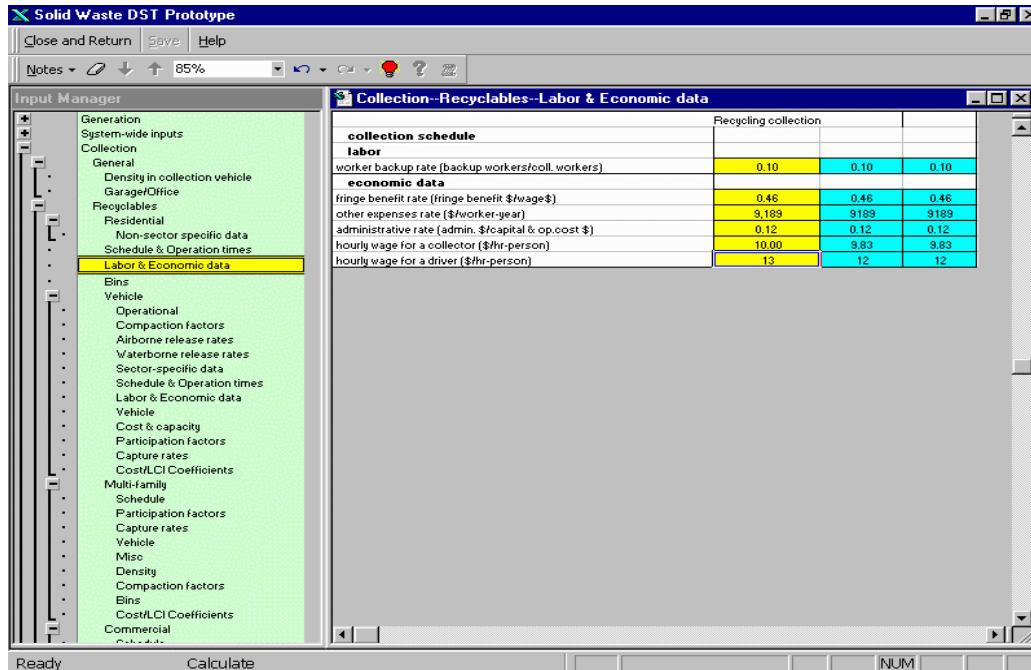
DESCRIPTION	VARIABLE NAME	Residential	Multifamily	Commercial
Yard Trimmings, Leaves	YTL	5.6%	5.6%	
Yard Trimmings, Grass	YTG	9.3%	9.3%	
Yard Trimmings, Branches	YTB	3.7%	3.7%	
Old News Print	ONP	6.7%	6.7%	2.2%
Old Corr. Cardboard	OCC	2.1%	2.1%	36.0%
Office Paper	OFF	1.3%	1.3%	7.2%
Phone Books	PBK	0.2%	0.2%	0.3%
Books	BOOK	0.9%	0.9%	
Old Magazines	OMG	1.7%	1.7%	
3rd Class Mail	MAIL	2.2%	2.2%	2.3%
Paper Other #1	PAOT1	0.0%	0.0%	0.0%
Paper Other #2	PAOT2	0.0%	0.0%	0.0%
Paper Other #3	PAOT3	0.0%	0.0%	0.0%
Paper Other #4	PAOT4	0.0%	0.0%	
Paper Other #5	PAOT5	0.0%	0.0%	
CCCR Other	CCR_O			1.9%
Mixed Paper	PMIX	0.0%	0.0%	
HDPE - Translucent	HDT	0.4%	0.4%	
HDPE - Pigmented	HDP	0.5%	0.5%	
PET	PPET	0.4%	0.4%	0.2%
Plastic - Other #1	PLOT1	0.0%	0.0%	
Plastic - Other #2	PLOT2	0.0%	0.0%	
Plastic - Other #3	PLOT3	0.0%	0.0%	
Plastic - Other #4	PLOT4	0.0%	0.0%	
Plastic - Other #5	PLOT5	0.0%	0.0%	
Mixed Plastic	PLMIX	0.0%	0.0%	
CCNR Other	CNR_O			4.1%
Ferrous Cans	FCAN	1.5%	1.5%	0.7%
Ferrous Metal - Other	FMOT	0.0%	0.0%	
Aluminum Cans	ACAN	0.9%	0.9%	0.4%
Aluminum - Other #1	ALOT1	0.0%	0.0%	
Aluminum - Other #2	ALOT2	0.0%	0.0%	
Glass - Clear	GCLR	3.9%	3.9%	1.9%
Glass - Brown	GBRN	1.6%	1.6%	0.8%
Glass - Green	GGRN	1.0%	1.0%	0.5%
Mixed Glass	GMIX	0.0%	0.0%	
CNNR Other	NNR_O			2.4%
Paper - Non-recyclable	PANR	17.1%	17.1%	
Food Waste	FW	4.9%	4.9%	
CCCN Other	CCN_O			17.1%
Plastic - Non-Recyclable	PLNR	9.9%	9.9%	
Misc.	MIS_CNN	7.5%	7.5%	
CCNN Other	CNN_O			11.3%
Ferrous - Non-recyclable	FNR	3.2%	3.2%	
Al - Non-recyclable	ANR	0.5%	0.5%	
Glass - Non-recyclable	GNR	0.7%	0.7%	
Misc.	MIS_NNN	12.3%	12.3%	
CNNN Other	NNN_O			10.7%



Step 5.3 Additional Inputs

ACTION:

- In the left Input Manager screen, go to **Collection / Recyclables / Labor and Economic Data**.
- If the **Collection** category is not already open, single click the + icon to the left of it to open its contents.
- Now single click on **Labor and Economic Data**.
- The following screen appears.
- Click on yellow cell to the right of **hourly wage for a collector (\$/hr.person)**. and enter **\$9.83**; press Enter.
- Click on yellow cell to the right of **hourly wage for a driver (\$/hr.person)**. and enter **\$12.00**; press Enter.
- Click on the **Close and Return** button to return to main screen.



5.3 SET TARGETS

At this point, you have defined all the parameters and established all baseline SWM criteria for Anytown, USA. Since the DST is a “Set Target-driven” tool, it now enables you to set various bounds on the baseline to examine a wide variety of SWM operation scenario options (see below section 5.5 Alternative Scenario Examples).

The Set Targets menu (see button on top command line above) is broken down into the three submenu categories of Cost/LCI, Unit Processes, and Define Diversion. Each of the three steps within this section will refer to a different submenu category:

Step 1: Set Targets - Cost/LCI

Step 2: Set Targets - Unit Process Flows

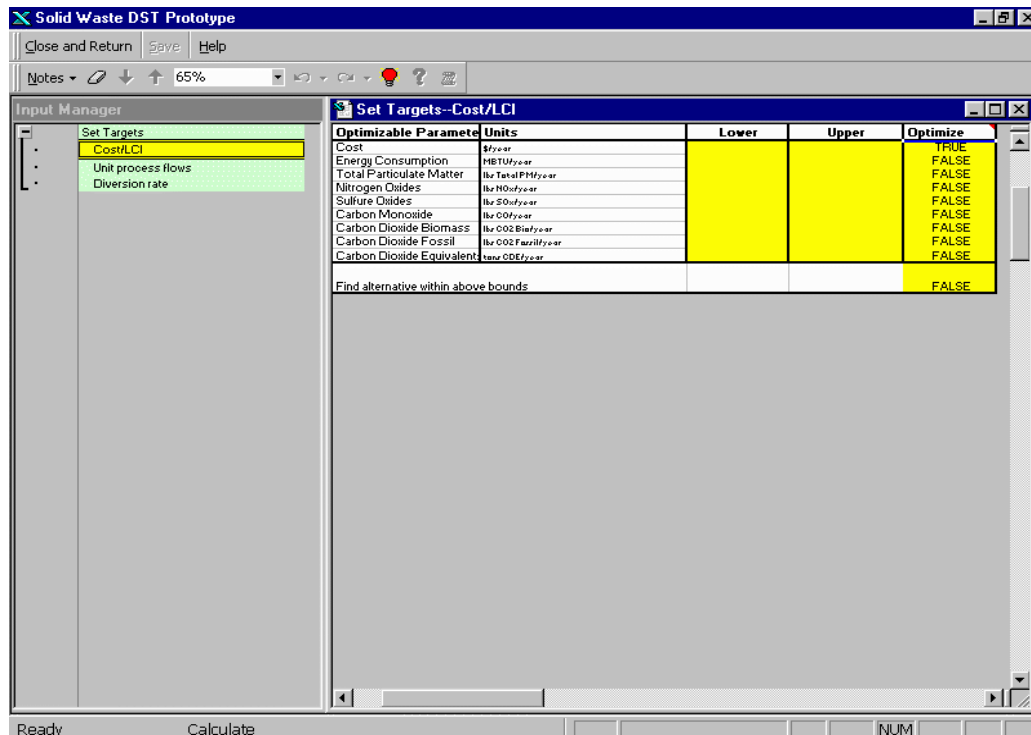
Step 3: Set Targets - Define Diversion

Step 1. Set Targets - Cost/LCI

There are nine parameters that can be optimized by the DST: cost, energy consumption, total particulate matter, nitrogen oxides, sulfur oxides, carbon monoxide, carbon dioxide biomass, carbon dioxide fossil, and carbon dioxide equivalents. Only one parameter can be optimized (**True**) at a time. You may select an optimization parameter based on the interests of your community.

ACTION:

- At the command line at top of screen, click **Set Targets** button.
- Select **Cost/LCI** from the pull down menu.
- The following screen appears.
- For Anytown, USA we want to optimize on **Cost**. Make sure that the yellow Optimize column is viewable (scroll to right) and Cost is **True** as seen above.
- Click on the **Close and Return** button to return to main screen.

**Step 2. Set Targets - Unit Process Flows**

This function allows you to put upper and lower bounds on the amount of waste that is processed by each unit operation. This function serves many purposes:

- *It allows the you to select the processes that are to be considered in the baseline scenario. Having an upper bound of zero for a mass flow in a unit processes precludes that unit process from being selected in the scenario. If the upper limit is removed, the unit process can be chosen in subsequent scenarios.*
- *This function of the tool can be used to dictate a minimum quantity of waste processed. For example, a lower bound of 1,000 tons on combustion, would model a combustion facility that operates with a minimum of 1,000 tons.*
- *The upper and lower bounds can be used to interactively search for solutions that meet minimum or maximum mass flows in unit processes included in the waste management*

system.

For Anytown, USA, it is necessary to input upper bounds of zero on unit processes that are not included in the baseline, but will be considered for additional scenarios. These unit processes include **R-Yardwaste**, **R-Commingled/Crew**, **R-Residual**, **MF-Pre-sorted**, **MF-Residual**, **C-Pre-sorted**, **C-Residual**, **Combustion** and **RDF**.

ACTION:

- At the command line at top of screen, click **Set Targets** button.
- Select **Unit Process Flows** from the pull down menu.
- The following screen appears.
- To set these bounds, enter upper bounds as **0** (zero) for **R-Yardwaste**, **R-Commingled/Crew**, **R-Residual**, **MF-Pre-sorted**, **MF-Residual**, **C-Pre-sorted**, **C-Residual**, **Combustion**, and **RDF**.
- Click on the **Close and Return** button to return to main screen.

Sector type	Short name	Bounds as mass	
		Lower	Upper
Collection	R-Yardwaste		0
Collection	R-MixedWaste		
Collection	R-Commingled/Crew		0
Collection	R-Residual		0
Collection	MF-MixedWaste		
Collection	MF-Pre-Sorted		0
Collection	MF-Residual		0
Collection	C-Pre-Sorted		0
Collection	C-MixedWaste		
Collection	C-Residual		0
Separation	Pre-sorted MRF		
Separation	Commingled MRF		
Treatment	Yardwaste Compost		
Treatment	Combustion		0
Treatment	RDF		0
Disposal	Landfill		
Disposal	Refr-Landfill		

Ste

Targets - Diversion Rate

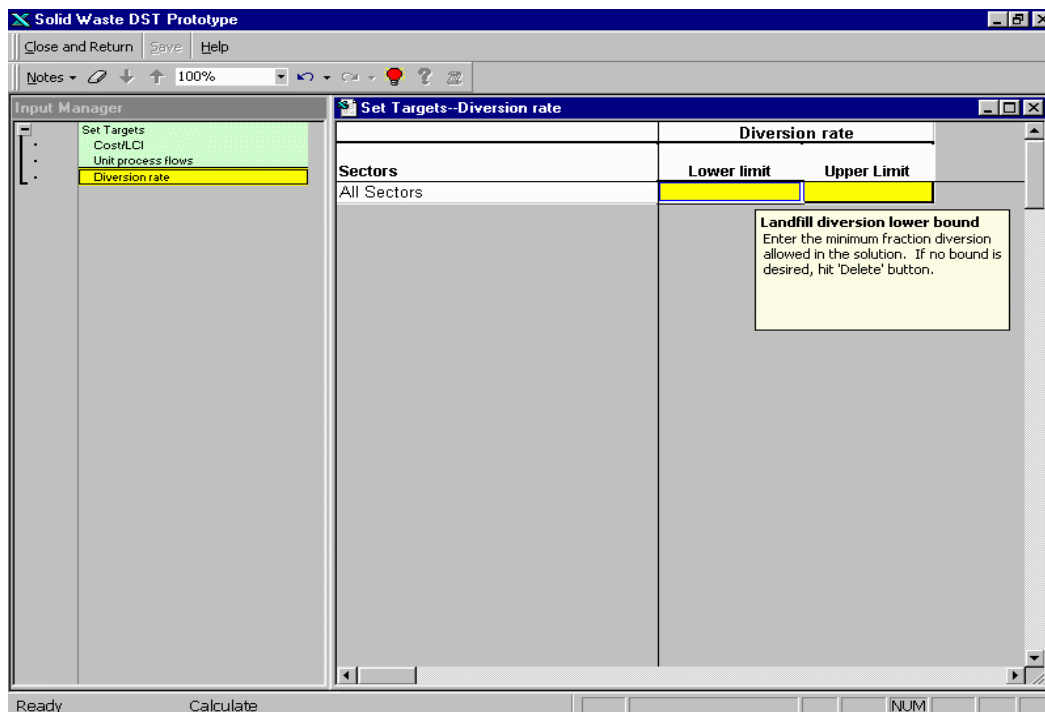
p 3. Set

A minimum or maximum diversion rate may be set as a constraint on the DST model. For example many communities have a goal of 25% diversion. Through this function of the tool, the

user may determine the optimal waste management strategy, given this diversion rate. For the baseline model a target diversion rate was not specified.

ACTION:

- At the command line at top of screen, click **Set Targets** button.
- Select **Diversion Rates** from the pull down menu.
- Verify that there is no diversion rate entered in the upper or lower bounds. The model will default to zero.
- Click on the **Close and Return** button to return to main screen.

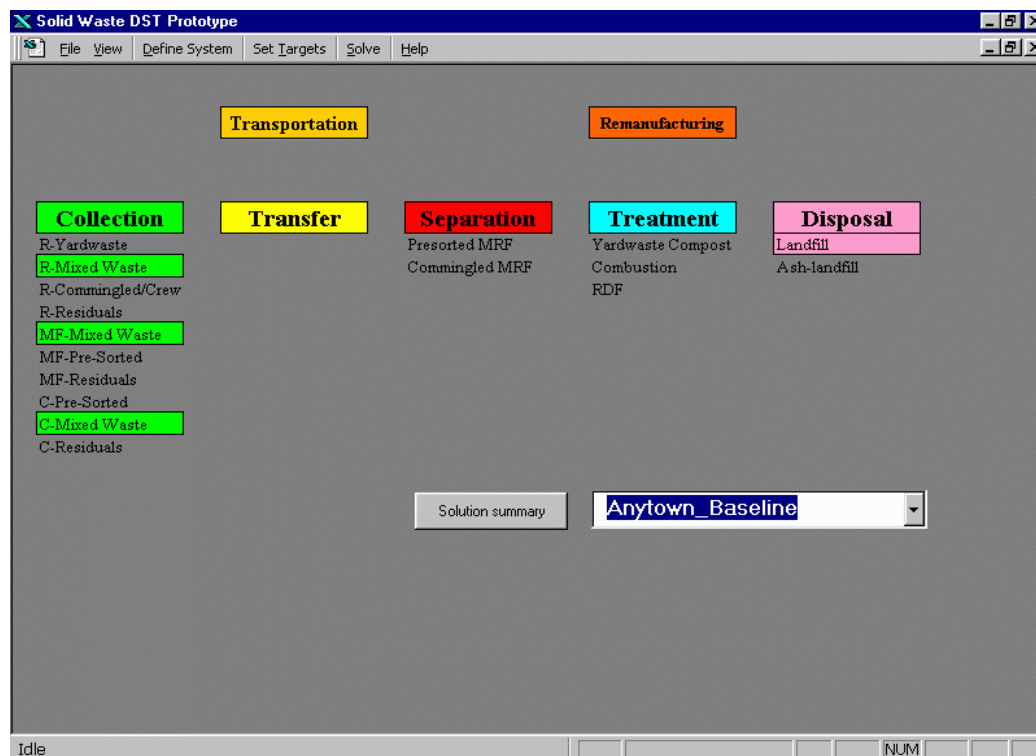


5.4 SOLVE

Before the baseline model is run, make sure that all data were input correctly. Once the model is run, no changes may be made within the “Define System” menu.

ACTION:

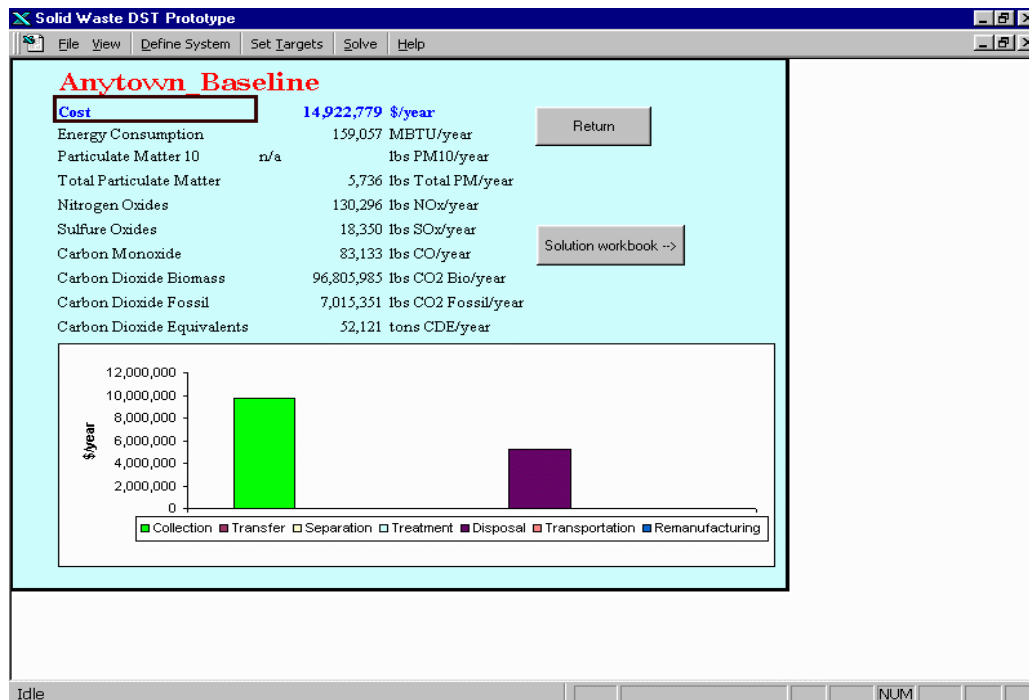
- At the command line at top of screen, click *Solve* button.
- Select *Run Optimizer* from the pull down menu.
- Enter a meaningful name for the baseline run, such as *Anytown_Baseline*, and press Enter at the prompt.
- Wait for results.
- The following screen appears



The results of this model represent the baseline, or current waste management system for Anytown, USA. As depicted in the above results screen, waste is collected by mixed waste collection and is then brought to a landfill for disposal. Notice the unit processes listed under each appropriate category. These are the ones that you enabled or identified for Anytown, USA in **Step 2. Define Systems -Unit Processes**. The highlighted waste types under the Collection category are the unit processes that are optimal for this scenario.

ACTION:

- Click on *Solution Summary* button.
- The following screen appears.



The above solution summary allows you to view the cost, energy, and environmental emissions of the baseline model. According to the DST model results, this waste management solution costs \$14,922,779 per year, requires 159,057 million BTUs of energy per year, and releases 52,121 lbs. per year of carbon dioxide equivalents.

The solution summary also presents a breakdown of the cost, energy, and environmental emissions by the waste management processes of collection, transfer, separation, treatment, and disposal. The screen capture shown here presents the cost of the baseline model broken down by collection and disposal processes.

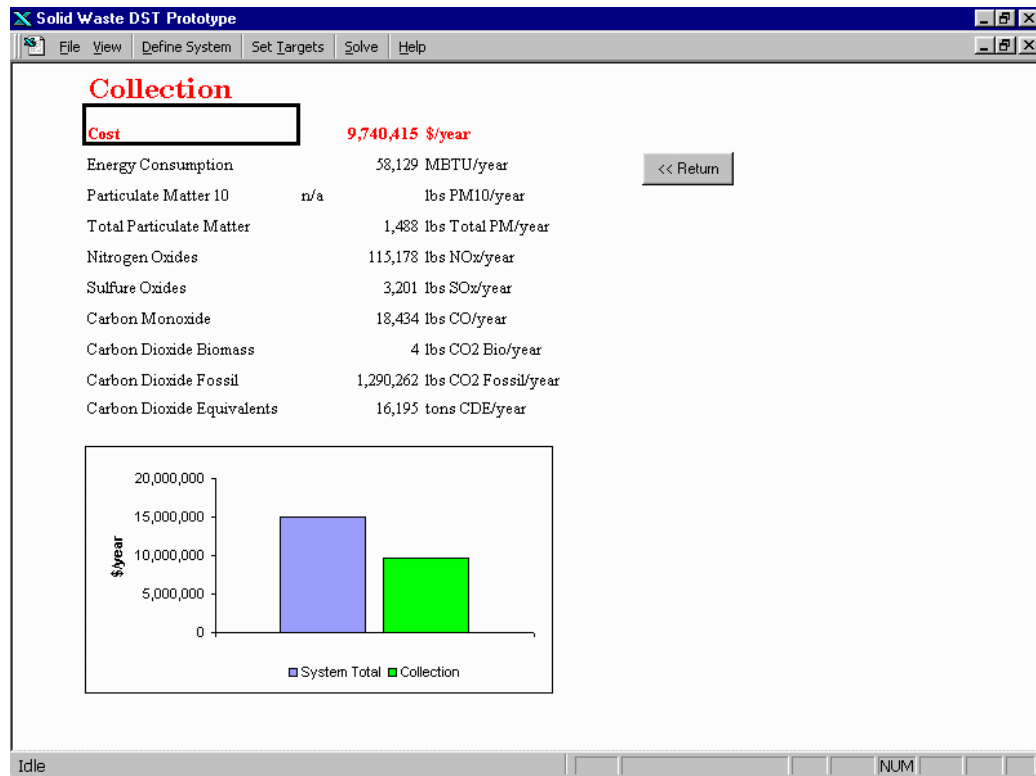
ACTION:

- Click on **Energy Consumption** to view the breakdown of energy.
- Click on the rest of the listed environmental emission items to view their breakdown equivalents.
- When you are finished, click on the **Return** button to return to the main screen.

A more detailed view of results can be seen by clicking on any one of the management processes categories - collection, transfer, separation, treatment, and disposal. For example, if **Collection** is selected (see below), the total cost, energy, and environmental emissions resulting from collection processes are presented. Additionally, a graph of the breakdown of cost, energy or environmental emissions is shown when the corresponding emission is selected.

ACTION:

- Right click on **Collection..**
- This provides the following chart of the cost, energy and environmental emissions from all collection options.
- When you are finished, click on the **Return** button to return to the main screen.



A more detailed view of a specific process, such as R-Mixed Waste, can be seen by clicking on that option.

ACTION:

- Right click on **R-Mixed Waste** under Collection.
- This provides the following chart of the cost, energy and environmental emissions from residential mixed waste collection.
- When you are finished, click on the **Return** button to return to the main screen.

Collection: R-Mixed Waste	
Total mass processed	105,120 Tons/yr
Yard Trimmings, Leaves	5,887 Tons/yr
Yard Trimmings, Grass	9,776 Tons/yr
Yard Trimmings, Branches	3,889 Tons/yr
Old News Print	7,043 Tons/yr
Old Corrugated Cardboard	2,208 Tons/yr
Office Paper	1,367 Tons/yr
Phone Books	210 Tons/yr
Books	946 Tons/yr
Old Magazines	1,787 Tons/yr
3rd Class Mail	2,313 Tons/yr
Paper Other #1	- Tons/yr
Paper Other #2	- Tons/yr
Paper Other #3	- Tons/yr
Paper Other #4	- Tons/yr
Paper Other #5	- Tons/yr
Combustible Compostable Recyclable Other	- Tons/yr
Mixed Paper	- Tons/yr
HDPE - Translucent	420 Tons/yr
HDPE - Pigmented	526 Tons/yr
PET	420 Tons/yr
Plastic - Other #1	- Tons/yr
Plastic - Other #2	- Tons/yr
Plastic - Other #3	- Tons/yr
Plastic - Other #4	- Tons/yr
Plastic - Other #5	- Tons/yr
Mixed Plastic	- Tons/yr
Combustible Non-Compostable Recyclable Other	- Tons/yr

Idle NUM

For a breakdown of the tonnage of waste constituents managed by this collection option, the following actions should be taken:

ACTION:

- Click on *more*.
- This provides the following chart of the cost, energy and environmental emissions from residential mixed waste collection.
- When you are finished, click on the *Return* button to return to the main screen.

5.5 ALTERNATIVE SCENARIO EXAMPLES

Using the *Anytown_Baseline* baseline model, the DST can be run for additional scenarios of waste management. This is where the real power of the system is evident. The following examples of these scenarios include an increase in the percentage of recycling, a change in collection methods, or the addition of a new management alternative, such as combustion or composting. The cost and environmental emissions resulting from this model run may then be compared to the baseline model to determine the increase or decrease in cost or emissions from the scenario.

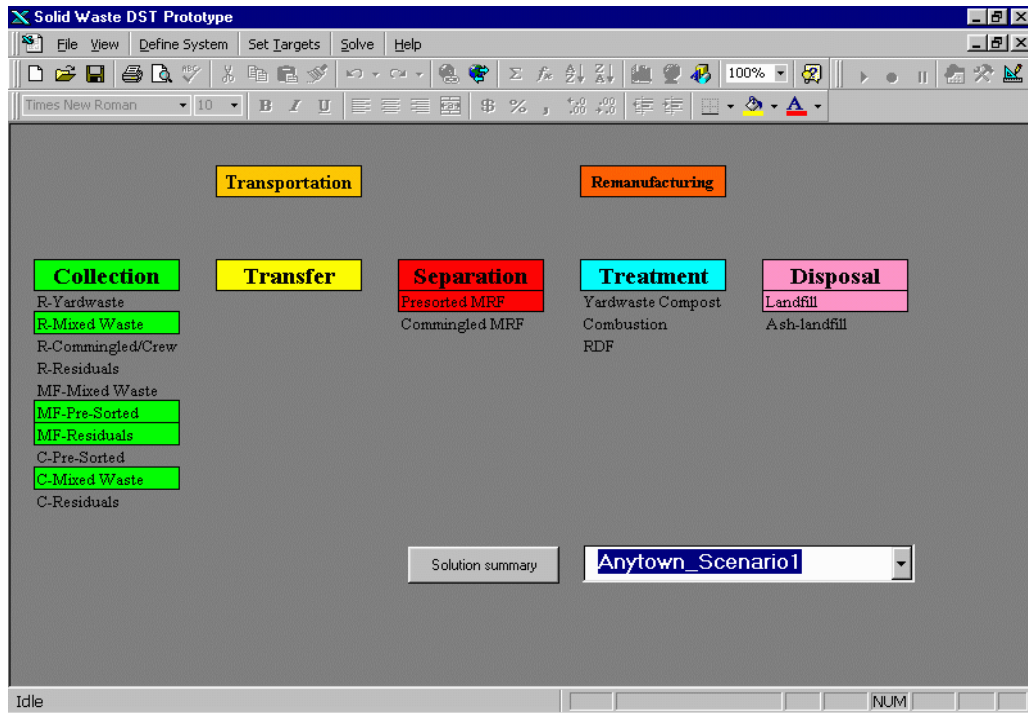
Scenario 1: Addition of Recycling - Optimize Cost

In Scenario 1 recycling options are enabled for all three waste management sectors. Therefore, depending on which option is more cost effective, mixed waste or recycling collection methods will be selected. To develop this scenario, the following steps are taken:

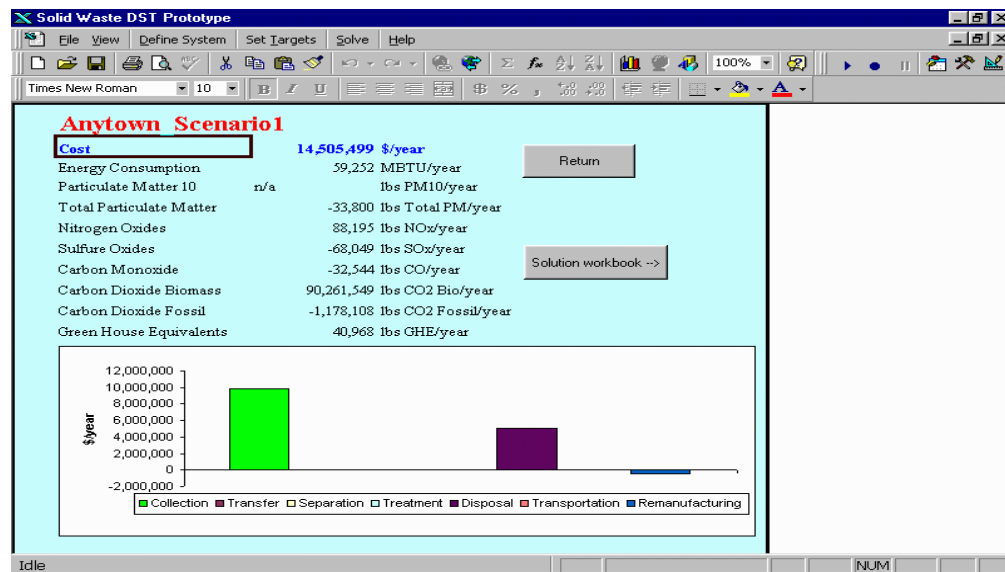
ACTION:

- At the command line at top of main screen, click *Set Targets* button.
- Select *Unit Process Flows* from the pull down menu.
- *Remove* zero bounds for **R- Commingled/Crew, R-Residual, MF-Pre-sorted, MF- Residual, C-Pre-sorted, and C-Residual.**
- Click on *Solve* button and *Run Optimizer* from the pull down menu.
- Name model run “*Anytown_Scenario1*” and press Enter.

As shown in the results screen for the Scenario 1 model, multifamily pre-sorted recyclables collection is now selected when optimizing on cost. This waste is then brought to a pre-sorted MRF for recycling. Residential and commercial waste is collected by mixed waste collection and disposed of at the landfill. This result leads to the conclusion that multi-family recycling is more cost effective than multi-family mixed waste collection.



Click **SolutionSummary** to view the cost, energy, and environmental emissions of the Scenario 1 model. According to the DST model results, this waste management solution costs \$14,505,499 per year, requires 59,252 million BTUs of energy per year, and releases 40,968 lbs. per year of greenhouse gas equivalents. Therefore Scenario 1 costs less, requires less energy, and produces fewer pounds of greenhouse gas equivalents when compared to the baseline model.



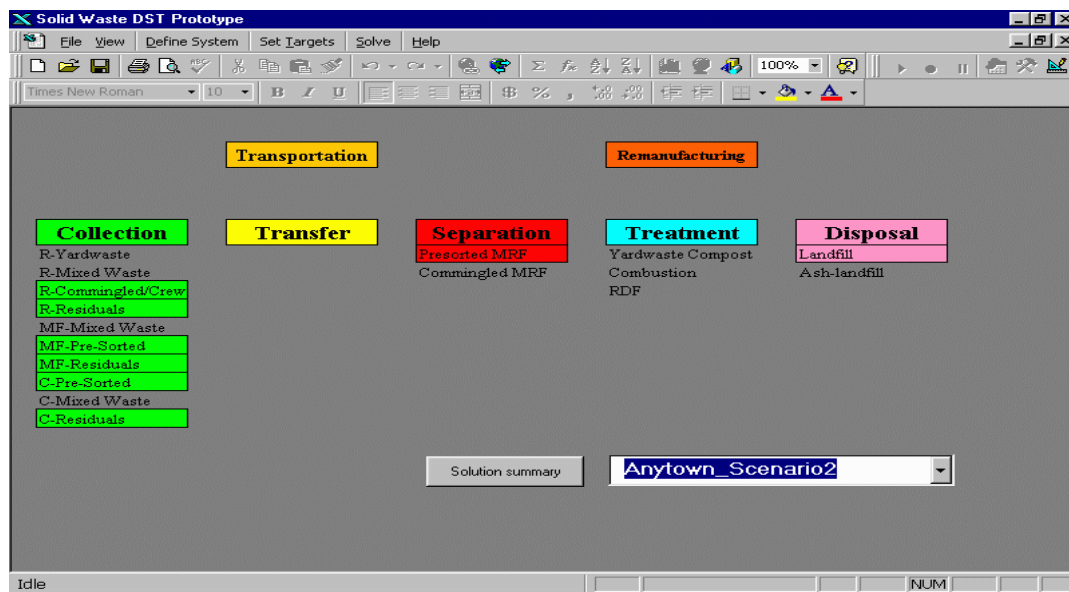
Scenario 2: Optimize Energy

Scenario 2 determines the optimal solution when minimizing energy instead of cost. Mixed waste and recyclables collection remain the available collection options within the system. To develop this scenario the following steps are taken:

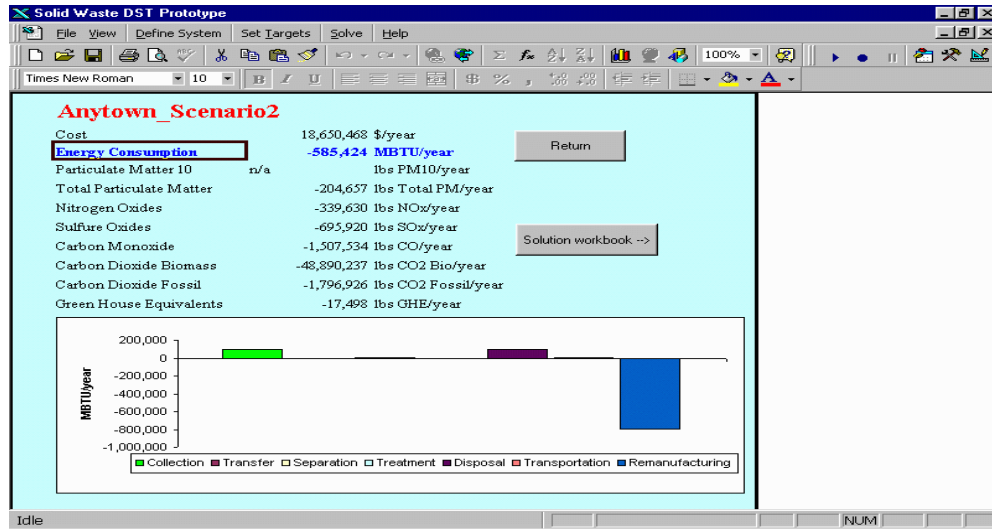
ACTION:

- At the command line at top of main screen, click *Set Targets* button.
- Select *Cost/LCI* from the pull down menu.
- Select *energy* as the optimized parameter.
- Click on *Solve* button and *Run Optimizer* from the pull down menu.
- Name model run *Anytown_Scenario2* and press Enter.

As shown in the results screen for the Scenario 2 model, waste in all three sectors is collected for recycling. This waste is then brought to a pre-sorted MRF for recycling, while residual waste is brought to a landfill for disposal. This result leads to the conclusion that recycling saves more energy than mixed waste collection and landfiling.



Click on *Solution summary* to view the cost, energy, and environmental emissions of the Scenario 2 model. According to the DST model results, this waste management solution costs \$18,650,468 per year, saves 585,424 million BTUs of energy per year, and saves 17,498 lbs. per year of greenhouse gas equivalents. Therefore, although Scenario 2 costs \$4 million more than the Baseline or Scenario 1 models, it produces large energy and carbon dioxide savings. These savings are the result of the remanufacturing offsets generated from the use of recyclables.



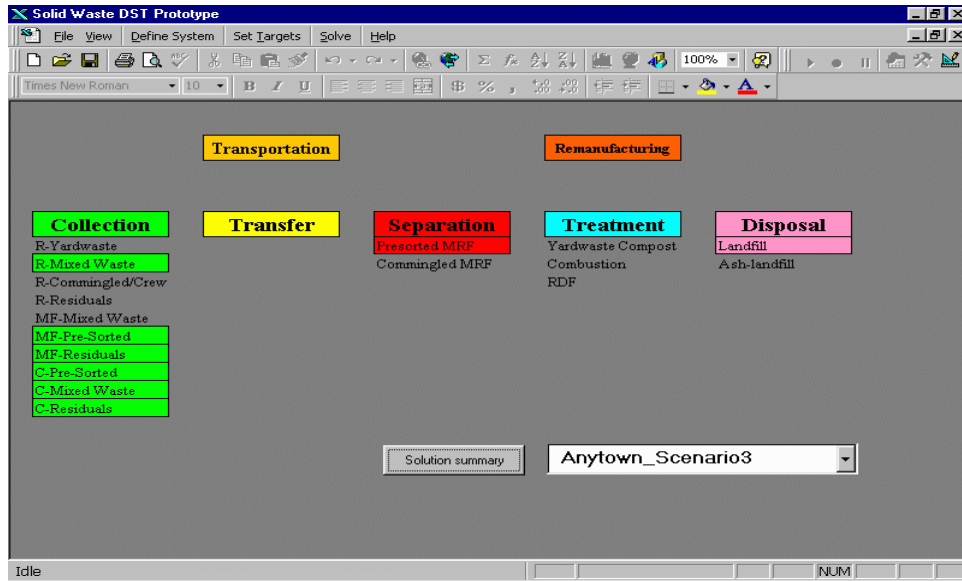
Scenario 3: Optimize Energy, with Upper Bound on Cost

Scenario 3 determines the optimal solution when optimizing energy with an upper bound of \$15 million set for cost. This forces the DST to determine a solution with minimum energy usage, but a cost similar to the Baseline model. Mixed waste and recyclables collection remain the available collection options within the system. To develop this scenario the following steps are taken:

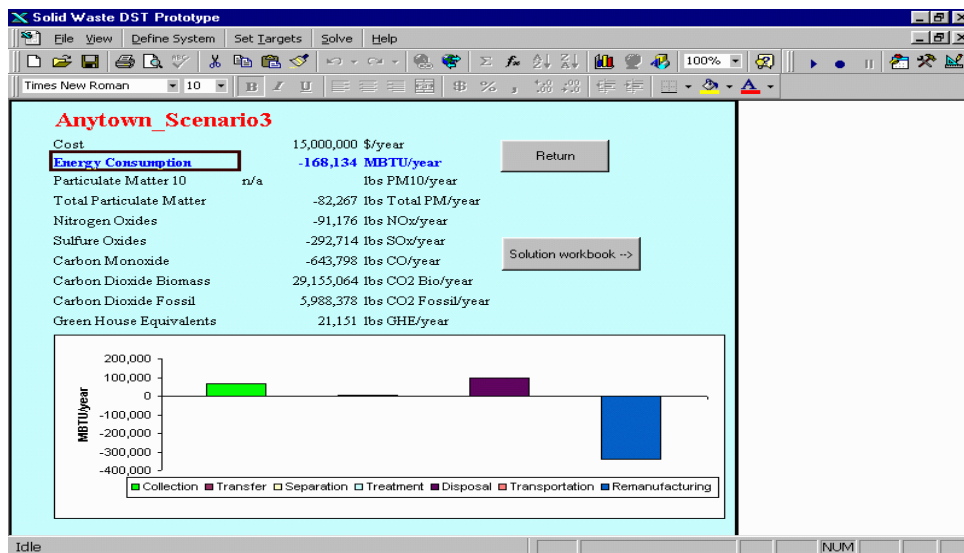
ACTION:

- At the command line at top of main screen, click *Set Targets* button.
- Select *Cost/LCI* from the pull down menu.
- Select *energy* as the optimized parameter.
- Set an upper bound of \$15,000,000 for cost.
- Click on *Solve* button and *Run Optimizer* from the pull down menu.
- Name model run *Anytown_Scenario3* and press Enter.

As shown in the results screen for the Scenario 3 model, waste is collected by pre-sorted collection methods in the multi-family and commercial sectors, and is then brought to a pre-sorted MRF for recycling. Additionally, waste is collected by mixed waste collection in the residential sector, as well as some of the waste in the commercial sector. This waste is then brought to the landfill for disposal.



Click on ***Solution Summary*** to view the cost, energy, and environmental emissions of the Scenario 3 model. According to the DST model results, this waste management solution costs \$15,000,000 per year, saves 168,143 million BTUs of energy per year, and releases 21,151 lbs. per year of greenhouse gas equivalents. Therefore, this scenario costs approximately the same as the Baseline scenario, but produces less energy savings, and releases more greenhouse gas equivalents. Note that these energy savings are significantly less than those for Scenario 2 (168,143 MBTU for Scenario 3 compared to 585,424 MBTU for Scenario 2).



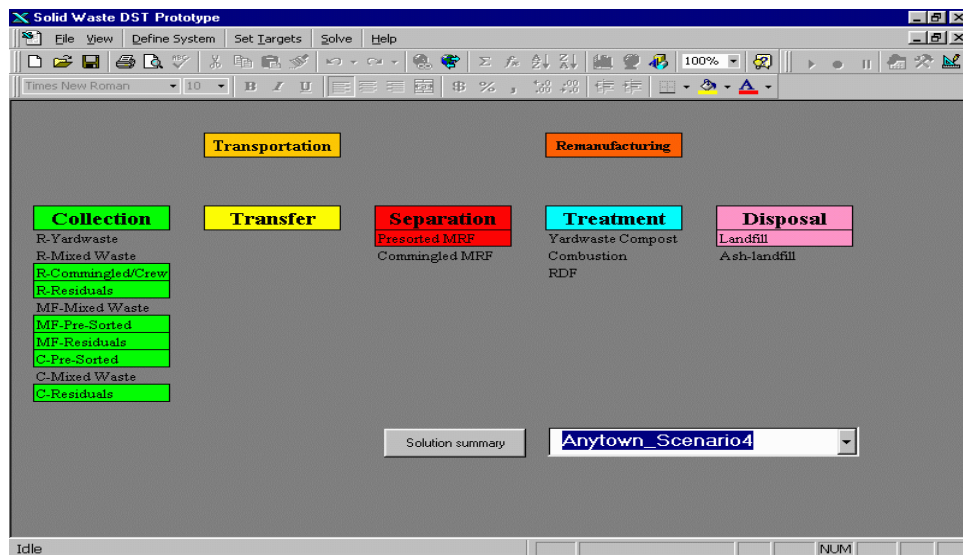
Scenario 4: Optimize Greenhouse Gas Equivalents

Scenario 4 determines an optimal solution when minimizing greenhouse gas equivalents instead of cost or energy. Mixed waste and recyclables collection remain the available collection options within the system. To develop this scenario the following steps are taken:

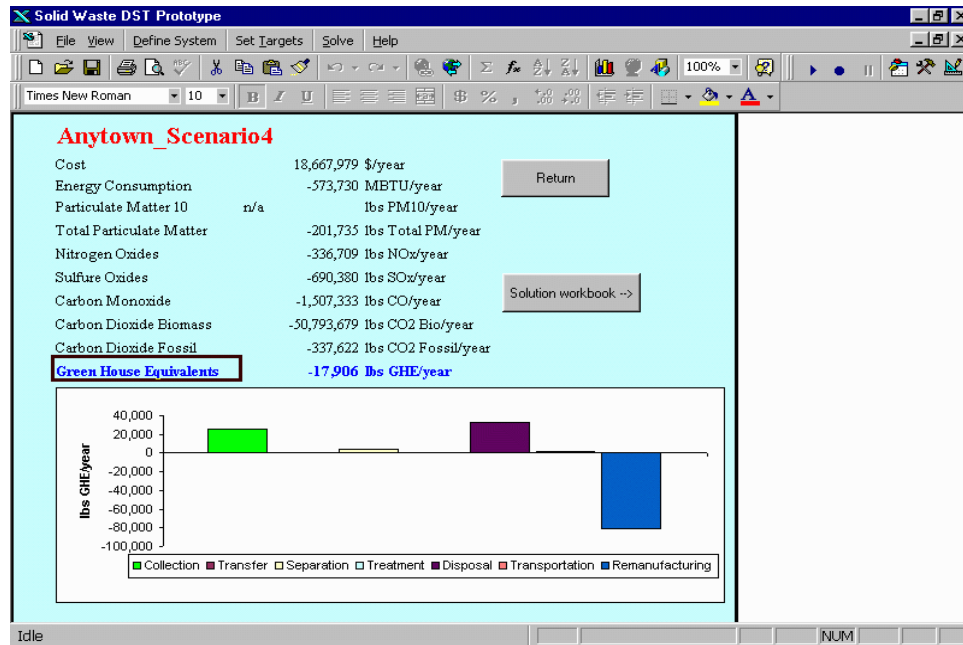
ACTION:

- At the command line at top of main screen, click *Set Targets* button.
- Select *Cost/LCI* from the pull down menu.
- Select *greenhouse gas equivalents* as the optimized parameter.
- Delete the upper bound of \$15,000,000 for cost.
- Click on *Solve* button and *Run Optimizer* from the pull down menu.
- Name model run *Anytown_Scenario4* and press Enter.

As shown in the results screen for the Scenario 4 model, waste in all three sectors is collected for recycling. This waste is then brought to a pre-sorted MRF for recycling, while residual waste is brought to a landfill. This result leads to the conclusion that recycling saves more greenhouse gas equivalents emissions than does mixed waste collection and landfilling.



Click on *solution summary* to view the cost, energy, and environmental emissions of the Scenario 4 model. According to the DST model results, this waste management solution costs \$18,667,979 per year, saves 573,730 million BTUs of energy per year, and saves 17,906 lbs. per year of greenhouse gas equivalents. Therefore, Scenario 4 has a comparable cost, and energy and greenhouse gas equivalents savings to Scenario 2 (Optimize energy).



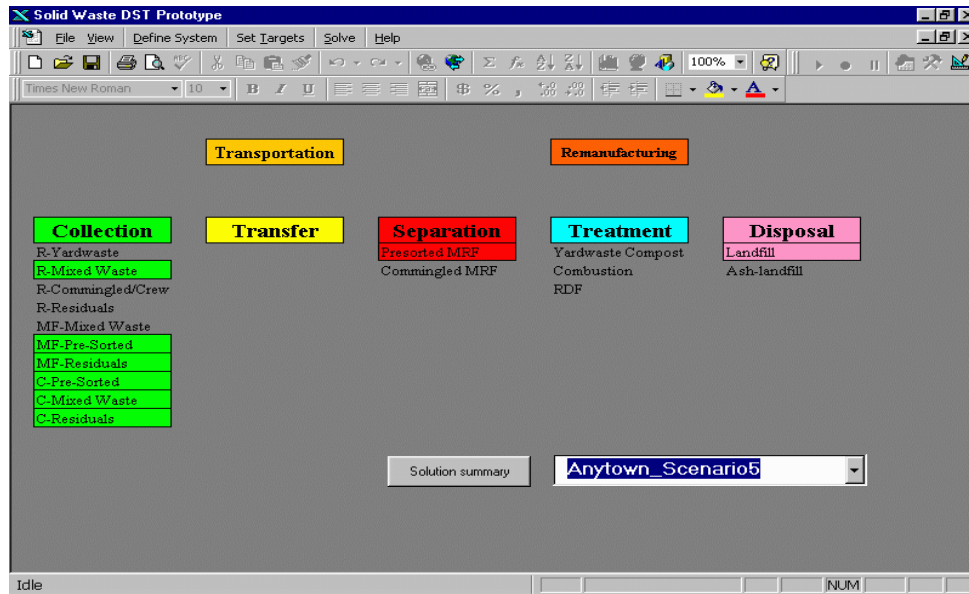
Scenario 5: Mandate of 5% Diversion

Scenario 5 determines the optimal solution when minimizing cost, while providing a mandatory 5% diversion rate to encourage recycling. Mixed waste and recyclables collection remain the available collection options within the system. To develop this scenario the following steps are taken:

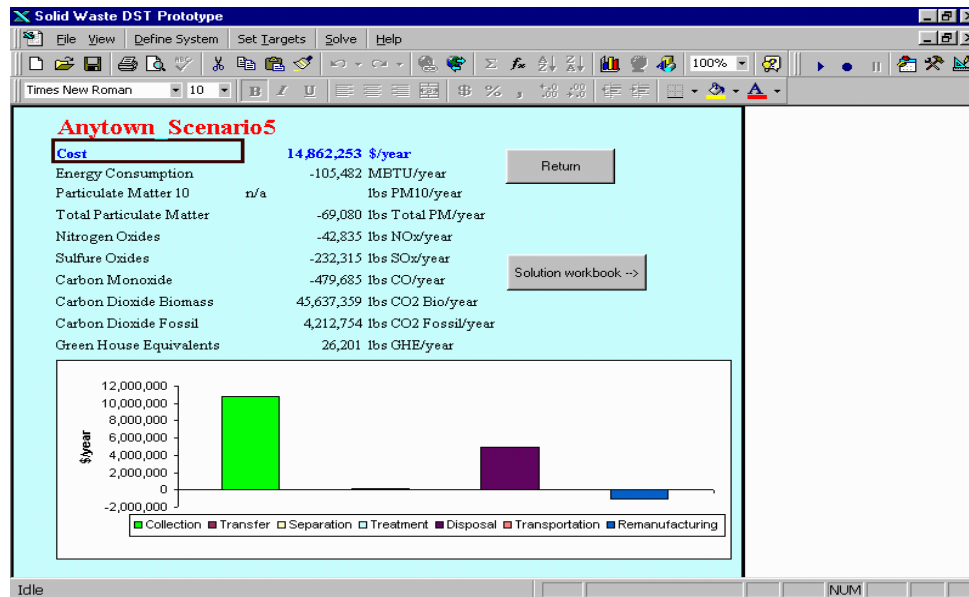
ACTION:

- At the command line at top of main screen, click *Set Targets* button.
- Select *Cost/LCI* from the pull down menu.
- Select *cost* as the optimized parameter.
- Select *Diversion Rate* from the *Set Targets* menu.
- Define a *5%* lower bound for diversion.
- Click on *Solve* button and *Run Optimizer* from the pull down menu.
- Name model run *Anytown_Scenario5* and press Enter.

As shown in the results screen for the Scenario 5 model, waste is collected by pre-sorted collection methods in the multi-family and commercial sectors, and is then brought to a pre-sorted MRF for recycling. Additionally, waste is collected by mixed waste collection in the residential sector, as well as some of the waste in the commercial sector. This waste is then brought to the landfill for disposal. This is a similar waste flow as for Scenario 3 (optimize energy with upper bound on cost).



Click on ***Solution Summary*** to view the cost, energy, and environmental emissions of the Scenario 5 model. According to the DST model results, this waste management solution costs \$14,862,253 per year, saves 105,482 million BTUs of energy per year, and generates 26,201 lbs. per year of greenhouse gas equivalents. Therefore, although this scenario has a cost comparable to the Baseline scenario, there are significant energy savings and reduction in carbon dioxide equivalent releases due to the 5% recycling.



Scenario 6: Mandate of 18% recycling

Scenario 6 pushes the limits of recycling by mandating an 18% diversion rate. The purpose of this scenario is to help determine the maximum diversion rate for this system. Mixed waste and recyclables collection remain the available collection options within the system. Note that composting is not yet available. To develop this scenario the following steps are taken:

ACTION:

- At the command line at top of main screen, click *Set Targets* button.
- Select *Diversion Rate* from the *Set Targets* menu.
- Define a *18%* lower bound for diversion.
- Click on *Solve* button and *Run Optimizer* from the pull down menu.
- Name model run *Anytown_Scenario6* and press Enter.

Note that this optimization fails, because there are not enough recyclable constituents in the waste stream to fulfill a diversion rate of 18%, when only allowing recycling. Once composting is enabled, this diversion rate is possible.

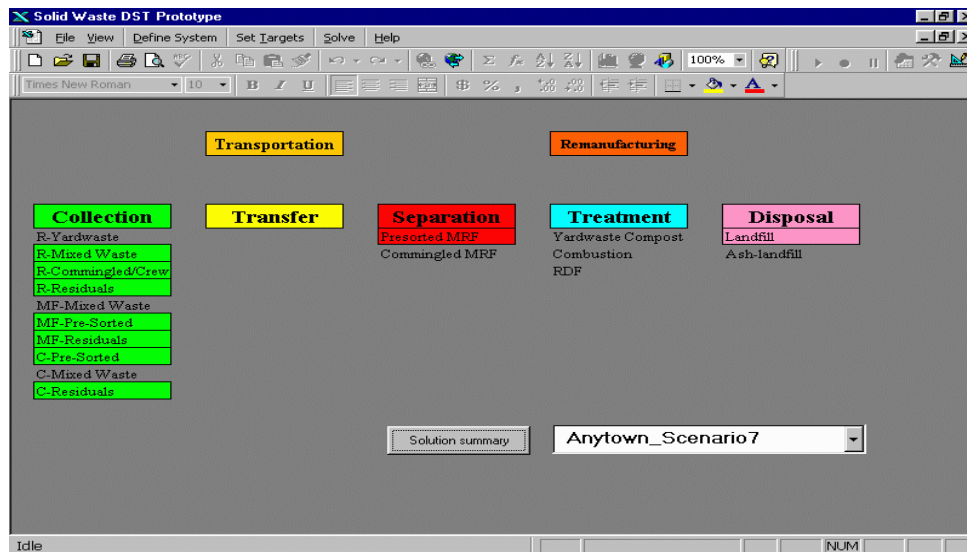
Scenario 7: Mandate of 14% recycling

Scenario 7 determines the maximum percent of available recyclables by mandating a 14% diversion rate. Mixed waste and recyclables collection remain the available collection options within the system. Note that composting is not yet available. To develop this scenario the following steps are taken:

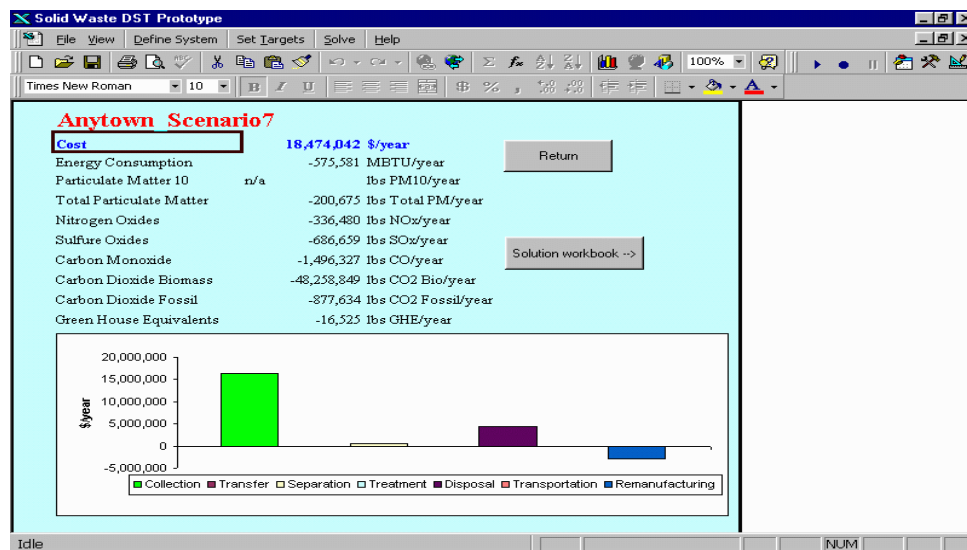
ACTION:

- At the command line at top of main screen, click *Set Targets* button.
- Select *Diversion Rate* from the *Set Targets* menu.
- Define a *14%* lower bound for diversion.
- Click on *Solve* button and *Run Optimizer* from the pull down menu.
- Name model run *Anytown_Scenario7* and press Enter.

As shown in the results screen for the Scenario 7 model, waste is collected by pre-sorted collection methods in all three sectors, and is then brought to a pre-sorted MRF for recycling. Waste is additionally collected by mixed waste collection in the residential sector. This waste is then brought to the landfill for disposal. Note that this is the maximum percentage of recycling, when not including composting.



Click on ***Solution Summary*** to view the cost, energy, and environmental emissions of the Scenario 7 model. According to the DST model results, this waste management solution costs \$18,474,042 per year, saves 575,581 million BTUs of energy per year, and saves 16,525 lbs. per year of greenhouse gas equivalents. Therefore, this scenario has a cost, and energy and carbon dioxide equivalent savings comparable to Scenarios 2 and 4 that optimize energy and greenhouse gas equivalents. This result leads to the conclusion that recycling although costly, saves energy and carbon dioxide equivalent releases.



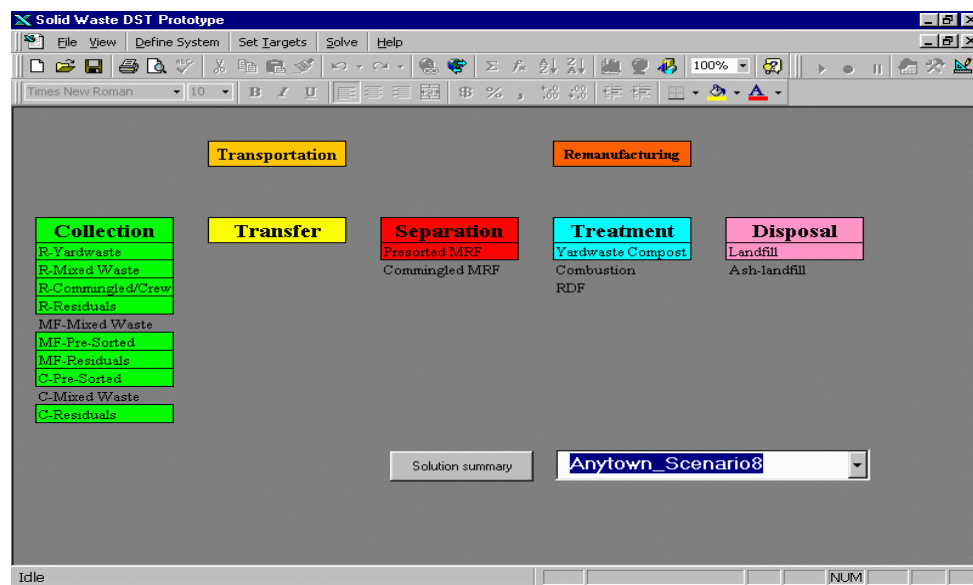
Scenario 8: Addition of Compost

In Scenario 8 composting is enabled for the residential sector. Mixed waste and recyclables collection also remain available collection options within the system. By enforcing a minimum diversion rate of 18%, the DST will be forced to recycle or compost as much material as possible. To develop this scenario the following steps are taken:

ACTION:

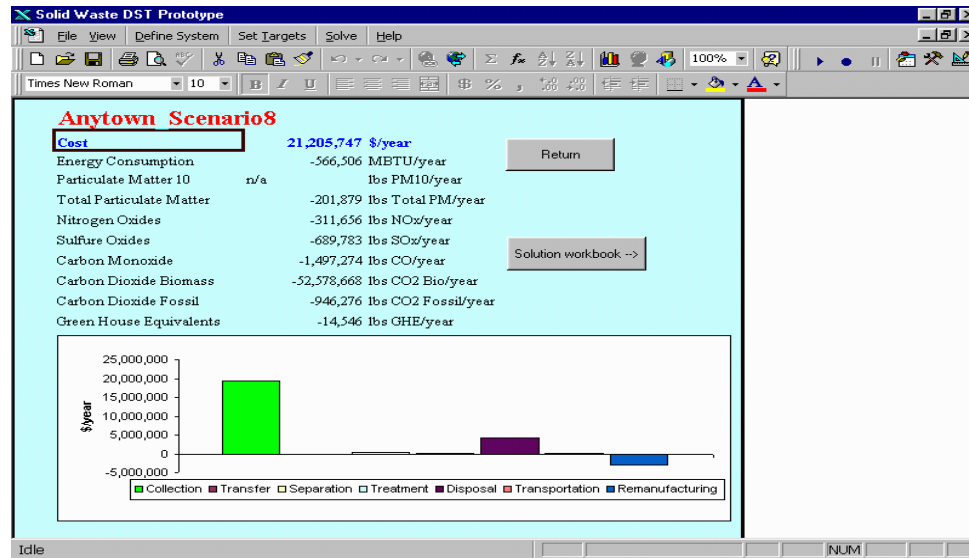
- At the command line at top of main screen, click **Set Targets** button.
- Select **Unit Process Flows** from the pull down menu.
- Remove **zero** bound from yard waste collection.
- Select **cost** as the optimized parameter.
- Select **Diversion Rate** from the **Set Targets** menu.
- Define a **18%** lower bound for diversion.
- Click on **Solve** button and **Run Optimizer** from the pull down menu.
- Name model run **Anytown_Scenario8** and press Enter.

As shown in the results screen for the Scenario 8 model, waste is collected by pre-sorted collection methods in all three sectors, and is then brought to a pre-sorted MRF for recycling. Waste is additionally collected by yard waste and mixed waste collection in the residential sector. Yard waste is brought to a compost facility, while mixed and residual waste is brought to the landfill for disposal. Note that this is the highest diversion rate possible, where diversion rate is defined to include both recycling and composting.



Click on **solution summary** to view the cost, energy, and environmental emissions of the

Scenario 8 model. According to the DST model results, this waste management solution costs \$21,205,747 per year, saves 566,506 million BTUs of energy per year, and saves 14,546 lbs. per year of greenhouse gas equivalents. Therefore, this scenario is more costly than any other scenario modeled so far. Meanwhile, the energy and greenhouse gas equivalents savings are comparable to Scenarios 2, 4, 6 and 7. Although these scenarios emphasize lower percentages of recycling, they seem more cost effective because they provide comparable energy and greenhouse gas equivalents savings, for a lower cost.



Scenario 9: Addition of Combustion and RDF Processing

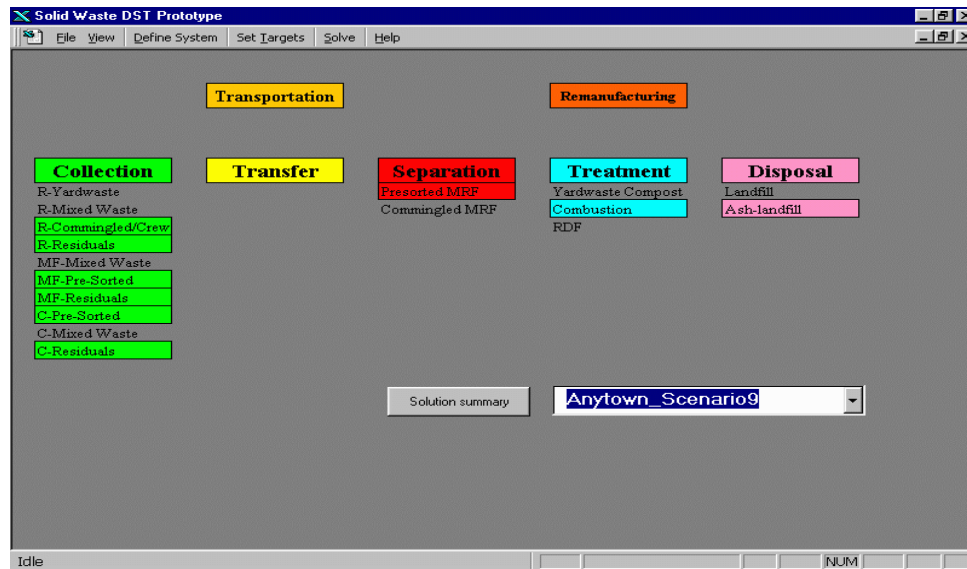
In Scenario 9 combustion and RDF management processes are enabled. Additionally, a minimum boundary of waste for the combustion option will force the DST to use this treatment method. To develop this scenario the following steps are taken:

ACTION:

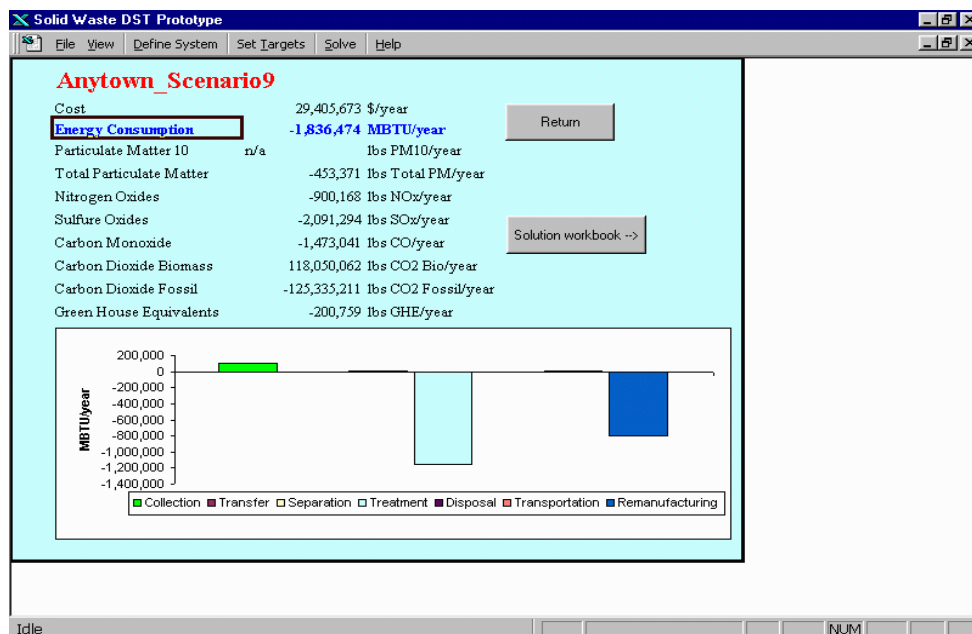
- At the command line at top of main screen, click **Set Targets** button.
- Select **Cost/LCI** from the pull down menu.
- Select **energy** as the optimized parameter.
- Select **Unit Process Flows** from the **Set Targets** menu.
- Remove **zero** bound from combustion and RDF management processes.
- Add lower bound of **1,000 tons** for combustion.
- Select **Diversion Rate** from the **Set Targets** menu.
- Define a **5%** lower bound for diversion.
- Click on **Solve** button and **Run Optimizer** from the pull down menu.
- Name model run **Anytown_Scenario9** and press Enter.

As shown in the results screen for the Scenario 9 model, waste is collected by pre-sorted

collection methods in all three sectors, and is then brought to a pre-sorted MRF for recycling. Residual waste is collected and brought to the combustion facility. Ash from the combustion facility is then brought to an ash landfill for disposal.



Click on *solution summary* to view the cost, energy, and environmental emissions of the Scenario 9 model. According to the DST model results, this waste management solution costs \$29,405,673 per year, saves 1,836,474 million BTUs of energy per year, and saves 200,759 lbs. per year of greenhouse gas equivalents. Therefore, this scenario is significantly more costly than any previously modeled scenario. On the other hand, the energy and greenhouse gas equivalents savings are significantly higher than any other scenario.



Scenario 10: Methods for Generating Alternatives

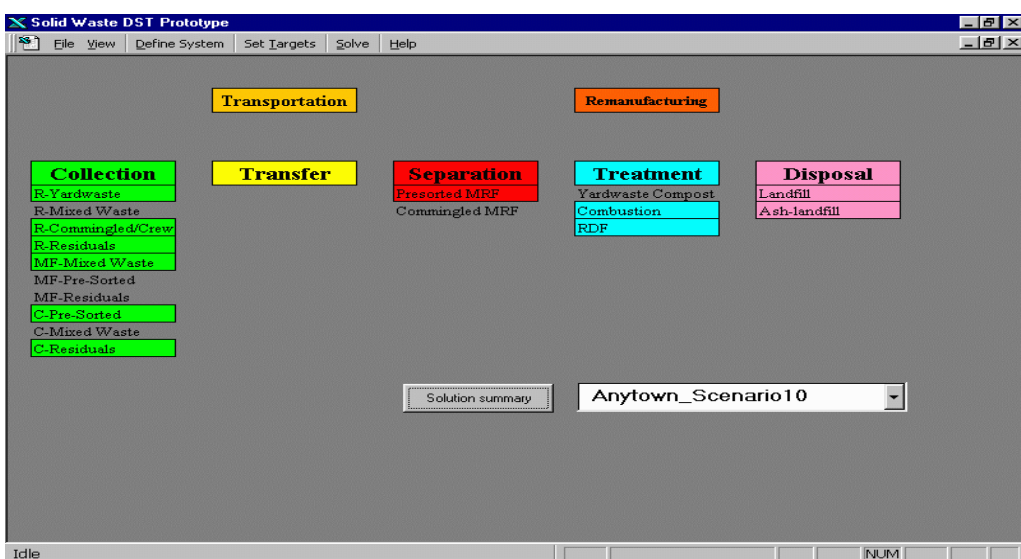
Methods for Generating Alternatives (MGA) is a way to relax a constraint to find solutions that are different from the optimal strategy, within a 10 percent bound of the optimal strategy. For Scenario 10, the optimal solution for Scenario 9, while minimizing energy, resulted in a savings of 1,836,474. Therefore an upper bound of 1,600,000 MBTU was set within the MGA constraint for energy. To develop this scenario the following steps are taken:

ACTION:

- At the command line at top of main screen, click *Set Targets* button.
- Select *Cost/LCI* from the pull down menu.
- Select *energy* as the optimized parameter.
- Enter an upper bound of 1,600,000 MBTU of energy.
- Click on *Solve* button and *Run Optimizer* from the pull down menu.
- Name model run *Anytown_Scenario10* and press Enter.

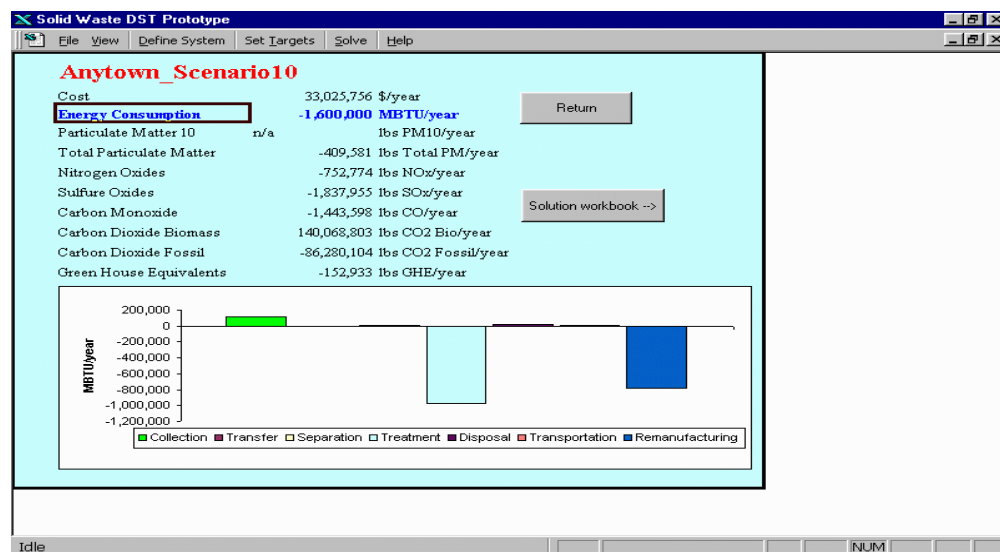
As shown in the results screen for the Scenario 10 model, residential waste is collected by yard waste, commingled/ crew recycling and residual collection methods, multi-family waste is collected by mixed waste collection, and commercial waste is collected by pre-sorted recyclables and residual collection. This waste is then brought to a pre-sorted MRF, a combustion facility, an RDF

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facility,
landfill
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combustion
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Click on ***Solution Summary*** to view the cost, energy, and environmental emissions of the Scenario 10 model. According to the DST model results, this waste management solution costs \$33,025,756 per year, saves 1,600,000 million BTUs of energy per year, and saves 152,933 lbs. per year of greenhouse gas equivalents. Therefore, this scenario provides a different solution to the bounds presented in Scenario 9. The solution for Scenario 10 provides a different selection of waste management options within a similar range of energy savings as for Scenario 9.



Scenario 11: Modeling Source Reduction

The purpose of Scenario 11 is to model source reduction using the DST. To adequately model source reduction, two key pieces of information are needed:

Part A. LCI aspects of not producing the materials that are source reduced, and

Part B. Cost and LCI aspects from managing a smaller quantity of waste in the system, e.g., collection costs and LCI may be lower due to the smaller quantity of waste being collected.

To develop this scenario the following steps are taken:

ACTION:

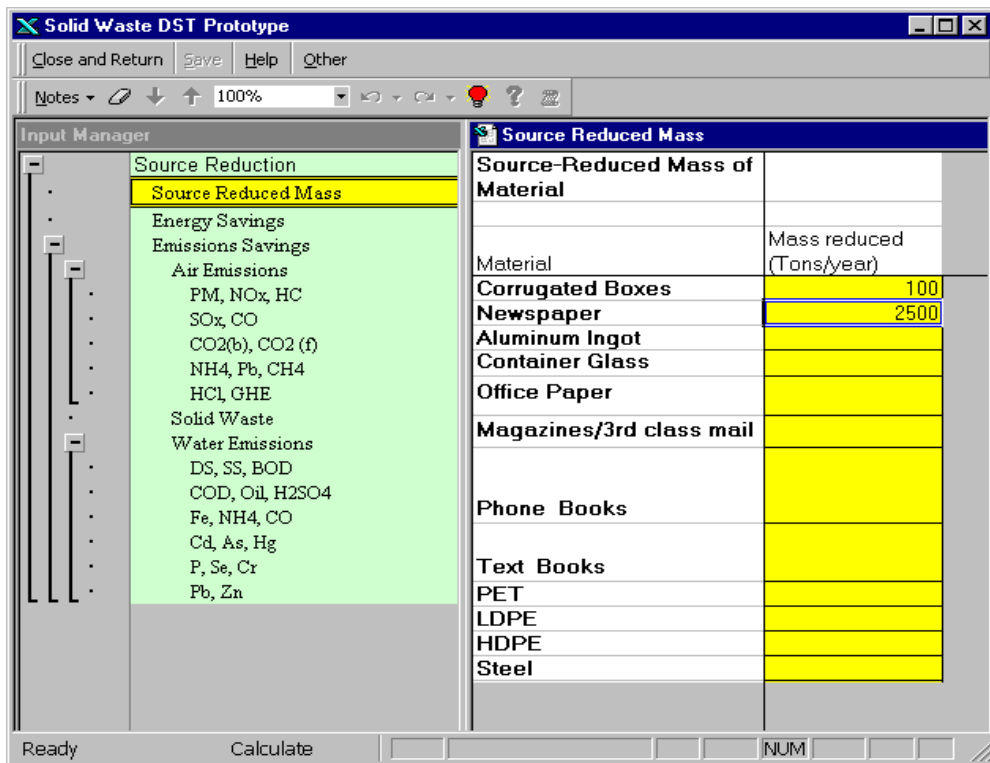
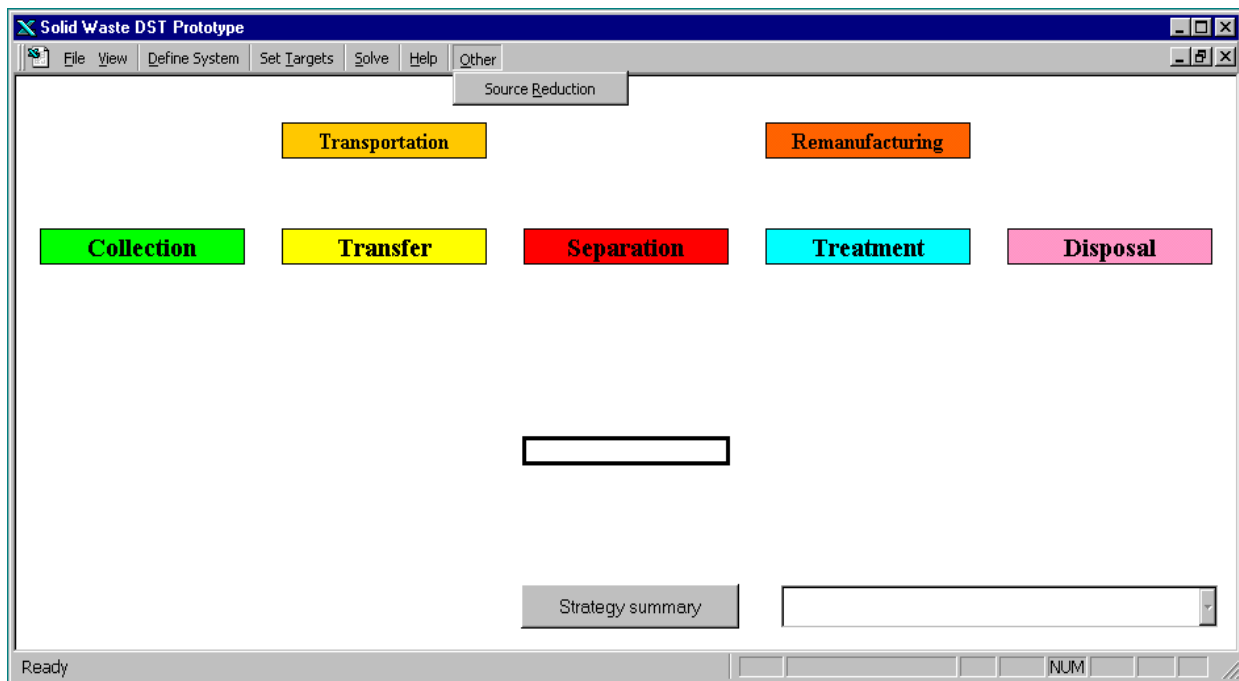
Part A:

- At the command line at top of main screen, click ***Other*** button from the menu.
- Click on ***Source Reduction***, and the Input Manager opens on the left side of the screen.
- Select the ***Source Reduced Mass*** option from the Input Manager.
- Enter the annual quantity of materials reduced in the ***Source Reduced Mass*** window on the right.
- After the quantities of materials source reduced are entered, select the LCI category of interest - energy, air emissions, solid waste, or water emissions to view the “savings” from source reduction of the material quantities entered.

Part B:

- Select ***Process Model Inputs*** from the ***Define System*** menu.
- Input new, lower generation rates for residential, multi-family, and/or commercial sectors.
- Select ***Cost/LCI*** from the ***Set Targets*** menu.
- Delete upper bound of 1,600,000 MBTU of energy.
- Select cost as optimized parameter.
- Click on ***Solve*** button and ***Run Optimizer*** from the pull down menu.
- Name model run ***Anytown_Scenario11*** and press Enter.

Part A. To calculate LCI aspects of not producing materials due to source reduction, a menu option titled “Other” is included in the DST’s main interface screen as seen in the figure below. The user selects the Other menu option, and selects Source Reduction, and an input worksheet is opened where the quantities of specific materials source reduced are entered. After the quantities of materials that are source reduced are entered, the LCI “savings” are viewed by clicking on the category of interest from the screen. The savings are associated with not having to produce the materials that were source reduced.



Recyclable Waste Item	SOx (lb/year)	CO (lb/year)
Old Corrugated Cardboard	-3.100E+03	-3.770E+03
Old newspaper	-1.243E+05	-2.725E+04
Aluminum Cans	0.000E+00	0.000E+00
Aluminum other 1	0.000E+00	0.000E+00
Aluminum other 2	0.000E+00	0.000E+00
Clear Glass	0.000E+00	0.000E+00
Brown Glass	0.000E+00	0.000E+00
Green Glass	0.000E+00	0.000E+00
Mixed Glass	0.000E+00	0.000E+00
Office Paper	0.000E+00	0.000E+00
Old Magazines	0.000E+00	0.000E+00
Third Class Mail	0.000E+00	0.000E+00
Phone Books	0.000E+00	0.000E+00
Text Books	0.000E+00	0.000E+00
PET	0.000E+00	0.000E+00
HDPE - Translucent	0.000E+00	0.000E+00
HDPE - Pigmented	0.000E+00	0.000E+00
Ferrous Cans	0.000E+00	0.000E+00
Ferrous Metals Other	0.000E+00	0.000E+00
Total	-1.274E+05	-3.102E+04

Part B. To capture the cost and LCI aspects of managing a smaller quantity of waste, the waste generation and composition input data have to be modified based on the specified level of source reduction. Because waste generation rates and waste composition change when a smaller quantity of waste is being managed, the DST will have to “rebuild” the model problem before any additional runs can be made. Once the model is rebuilt with the new waste generation and composition data, future scenarios will use this new generation rate and composition when calculating model results.

Recalculating Waste Generation, Composition, and Capture Rates

The description that follows assumes that the user first uses the DST without source reduction, then reduces some quantities of materials from the waste stream, and uses the DST again for the smaller quantity of waste. The DST *does not* automatically adjust the waste composition and generation based on the waste quantities that are source reduced in Part A. The source reduction calculation tool is independent of the DST calculations.

To calculate the new waste generation rate and waste composition numbers after the source reduction quantities are accounted for, the following steps are necessary:

- Knowing which sector’s (residential, multi-family, or commercial) waste items are source reduced
- Back-calculating the new waste composition based on the new quantities of waste generated after accounting for source reduction
- Based on the new quantities of waste and recyclables generated, back-calculate the waste

generation rate and the capture rates for recyclables

- Enter the new generation, composition, capture rates into the DST and continue model runs with the smaller quantity of waste generated that includes source reduction

Note that the calculations and procedure to estimate benefits of source reduction does not include any costs incurred by the community for the source reduction programs. To capture the costs of source reduction, the costs of these programs are to be added to the waste management costs reported by the DST. Also refer to ***Section 2.2.1 Source Reduction*** for more information on source reduction and the limitations of the way source reduction is modeled using the DST.