Solid Waste Modeling Support for the Virgin Islands Waste Management Authority

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Executive Summary

RTI International (RTI) was contracted by the Virgin Islands Waste Management Authority (VIWMA) to applying RTI's in-house municipal solid waste decision support tool (MSW DST) to analyze predefined future solid waste management strategies for the island of St. Croix. These strategies were developed by the VIWMA in coordination with the St. Croix citizen's advisory committee. The data and information generated from this analysis is intended for use in supporting the solid waste management planning and decisionmaking for St. Croix.

The analysis focused on the MSW stream for the entire island and included the waste management options of recycling, composting, waste-to-energy (WTE) and landfill disposal. The design of the waste management strategies analyzed is as follows:

1) **Current Conditions:** minimal (2 percent) recycling with the remaining waste landfilled.
2) **2007 Scenario:** increase in recycling to 5 percent and the addition of yard waste composting (10 percent) with the remaining waste landfilled.
3) **2009 Scenario:** increase in recycling to 10 percent, an increase yard waste composting to 20 percent, the addition of waste-to-energy (WTE) at 30 percent, with the remaining waste landfilled
4) **2013 Scenario:** increase in recycling to 15 percent, a constant yard waste composting of 20 percent, an increase in WTE to 45 percent, with the remaining waste landfilled.

Total annual cost, energy consumption, and multi-media emissions were calculated using MSW DST. The MSW DST is a computer-based model developed by RTI in cooperation with the U.S. Environmental Protection Agency (EPA) Office of Research and Development to assist communities and MSW planners in analyzing the full costs and life cycle environmental aspects of alternatives for MSW management. The MSW DST is populated with North American average default data, which has been modified to use specific St. Croix data. Users can evaluate the numerous MSW management strategies that are feasible within a community or region and identify the alternatives that are economically and environmentally efficient, making tradeoffs if necessary. The MSW DST has undergone extensive stakeholder input and peer review (as well as a separate peer review by the U.S. EPA) and is regarded as a cutting-edge software tool that can help solid waste planners make more informed decisions.

The general design and assumptions for the recycling, composting, waste-to-energy (WTE) and landfill disposal processes analyzed are as follows:

- **Recycling** assumes a mix of manual and mechanical separation at a materials recovery facility (MRF). Items recovered are assumed to be shipped off-island to the mainland U.S. and South America for remanufacturing into new products. Residual wastes from the MRF are sent to the landfill for disposal.

- **Composting** assumes an organics compost facility would be employed using a windrow type process. Waste flowing to the compost facility is screened, shredded and placed in windrows for curing for 4-6 months. The final compost product is used primarily as a soil amendment. Residual wastes from the compost operation are sent to the landfill for disposal.

- **Waste-to-Energy** is added in the 2009 and 2013 scenarios and it is assumed to be a mass-burn type design with electrical energy production and ferrous metal recovery from the ash. The combustion ash is sent to the landfill for disposal.

- **Landfill** disposal assumes that the landfill is designed and operated as a U.S. Subtitle D type landfill. The landfill would contain a liner system and collect and manage leachate. For landfill gas, it was assumed that any gas produced would be vented to the atmosphere.

The results of this analysis are useful for identifying the potential cost and environmental implications of the predefined future MSW management scenarios and to demonstrate tradeoffs exist between cost and environmental performance. In general, it appears that the higher the materials and energy recovery rates, the better the environmental performance. However, increasing recycling and energy recovery (i.e., WTE) in particular can lead to higher waste management costs.

1.0 Introduction

The VIWMA is working with a St. Croix citizen's advisory committee to develop a solid waste management plan for the island. As part of the plan development, the VIWMA and citizen's advisory committee identified future solid waste management strategies for consideration and analysis. These strategies were analyzed using RTI's in-house MSW DST that was developed in cooperation with the U.S. EPA and RTI. The MSW DST computer model has been developed with an emphasis on objectivity and scientific credibility and has undergone extensive stakeholder input and peer review, as well as a separate EPA peer review.

The methods used in the MSW DST to calculate the energy and environmental results are built on the principles of Life Cycle Assessment (LCA). LCA is a type of systems analysis that accounts for the complete set of upstream and downstream (cradle-to-grave) energy and environmental aspects associated with industrial systems. The technique examines the inputs and outputs from every stage of the life cycle from the extraction of raw materials, through manufacturing, distribution, use/reuse, and waste management. In the context of integrated waste management systems, an LCA tracks the energy and environmental aspects associated with all stages of waste management from waste collection, transfer, materials recovery, treatment, and final disposal. For each of the waste management operations, energy and material inputs and emissions and energy/material outputs are calculated (see Figure 1). In addition, the energy and emissions associated with fuels, electrical energy, and material inputs are captured. Likewise, the potential benefits associated with energy and/or materials recovery displacing energy and/or materials production from virgin resources are captured.

Taking a life-cycle perspective encourages waste planners to consider the environmental aspects of the entire system including activities that occur outside of the traditional framework of activities from the point of waste collection to final disposal. For example, when evaluating options for recycling, it is important to consider the net environmental benefits (or additional burdens) including any potential displacement of raw materials or energy. Similarly, when electricity is recovered through the combustion of waste or landfill gas, the production of fuels and generation of electricity from the utility sector is displaced.

As illustrated in Figure 1, each waste management activity consumes energy and materials, and creates air and water emissions. Some waste management activities also recover energy and materials. The benefits associated with the recovery of energy and materials are captured in this study. For example, when energy is recovered through landfill gas-to-energy, the generation of electricity from the utility sector is displaced. The benefit associated with the displaced production of that electricity from the utility sector is captured in the landfill results. Similarly, when a material (e.g., metal) is recovered from recycling, energy and emissions associated with the extraction and processing of virgin materials are avoided. The avoided energy and emissions are accounted for in the life cycle results.

2.0 Project Goals

The overall goal of this study is to provide the VIWMA with a more detailed and quantitative understanding of the cost and environmental aspects and tradeoffs among proposed future strategies for managing St. Croix's solid waste. The results from this analysis will be used by the VIWMA and the St. Croix citizen's advisory committee to support the development of an integrated MSW management plan for the island of St. Croix.

The data and results generated through this project provide a general assessment of the potential tradeoffs in cost, energy, and emissions associated with the management of solid waste for St. Croix. An analysis of other facilities or regions may produce different results.

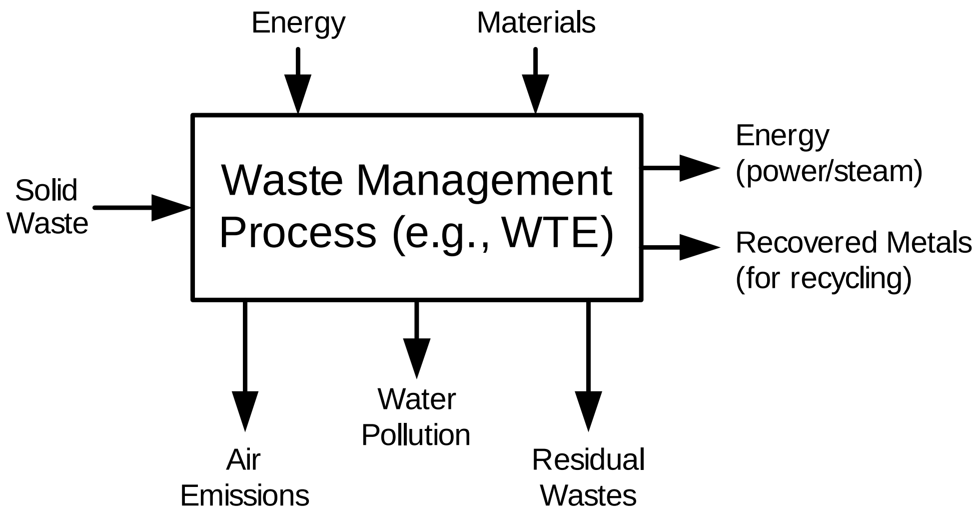

Figure 1. Life Cycle Inputs and Outputs of a Waste Management Process.
All waste management processes that comprise an integrated waste management system consume energy and materials and produce emissions. Some processes, such as WTE, recover energy and materials. The benefits associated with any energy or materials recovered are captured in the life cycle study.

3.0 Waste Management Scenarios Analyzed

To meet the goals of this project, the following MSW management strategies, as designed by the VIWMA in cooperation with the citizen's advisory committee, were analyzed:

1) **Current Conditions:** minimal (2 percent) recycling with the remaining waste landfilled.
2) **2007 Scenario:** increase in recycling to 5 percent and the addition of yard waste composting (10 percent) with the remaining waste landfilled.
3) **2009 Scenario:** increase in recycling to 10 percent, an increase yard waste composting to 20 percent, the addition of waste-to-energy (WTE) at 30 percent, with the remaining waste landfilled
4) **2013 Scenario:** increase in recycling to 15 percent, a constant yard waste composting of 20 percent, an increase in WTE to 45 percent, with the remaining waste landfilled.

Table 1 lists the mass flow of waste defined for each strategy. The following assumptions and conditions were applied to all strategies analyzed (as appropriate):

- Waste generation was assumed to be 130,000 tons in the current year and increased by 2 percent per year afterwards.
- Waste composition, as shown in Table 2, was based on 2000 waste sort data collected at the Anguilla Landfill by the Antilitter and Beautification Commission.

- 100-year time frame was used for estimating landfill gas emissions.
- Landfill gas was assumed to be vented. That is, it was assumed that no gas collection system was in-place or planned.
- Electrical energy produced at from WTE was assumed to offset base loaded oil-fired electrical energy production.

Key assumptions by waste management operation are listed in Table 3.

Table 1. Mass Flow of Waste Used in the Scenarios Analyzed (tons).

	Current	**2007**	**2009**	**2013**
Waste Generated	*130,000*	*132,600*	*135,252*	*137,957*
Source Reduction	*0*	*2,210*	*4,420*	*6,630*
Waste Collection	130,000	130,390	130,832	131,327
MRF	2,600	6,520	13,083	19,699
Compost	0	13,039	26,166	39,398
WTE	0	0	39,250	59,097
Landfill	125,000	85,757	46,294	6,566

Table 2. St. Croix Waste Composition.

Constituent	**Percent Composition by Mass**
Paper	9.8%
Plastics	5.7%
Metals	19.6%
Glass	3.2%
Compostable Organics	38.5%
Misc	23.2%
TOTAL	**100%**

The analysis was conducted using RTI's MSW DST. As mentioned above, this tool was developed through a cooperative research agreement between RTI and the U.S. EPA and has undergone stakeholder, peer, and EPA review. Additional information about the MSW DST is supplied in Attachment A and can be obtained from RTI.

Table 3. Key Assumptions By Process Used in This Analysis.

Parameter	**Assumption**
General	
Waste Generation	See Table 1
Waste Composition	St. Croix specific (See Table 2)
Waste Collection Frequency	1 time per week
Transportation Distances	
Collection to MRF	10 miles one way
Collection to Compost	10 miles one way
Collection to WTE	10 miles one way
Collection to Landfill	10 miles one way
MRF	
Basic Design	Semi-automated
Compost	
Basic Design	MSW in-vessel compost
Compost Aeration Time	3 weeks
Compost Curing Time	4-6 months
Compost Turning Frequency	2 times per month
WTE	
Basic Design	Mass burn
Plant Heat Rate	17,500 btu/kwh
Ferrous Recovery	90%
Utility Sector Offset	Offset is baseload oil–fired electricity production.
Landfill	
Basic Design	Conventional, Subtitle D Type
Time Period for Calculating Emissions	100 years
Landfill Gas Collection Efficiency	0% (gas is vented)
Landfill Gas Management	None (gas is vented)

4.0 Results

The summary level results for each scenario analyzed are shown in Table 4. Results are presented as net totals for each scenario and waste management activity. Therefore, a positive value represents a net cost or emission whereas a negative value represents a net cost, energy, or emissions savings/avoidance. For example, the negative value for tons of carbon equivalent means that the waste management strategy offsets (or avoids) more carbon equivalent emissions than it produces by energy and materials recovery and displacing utility sector energy production and/or materials production from virgin resources respectively.

Results for annual cost, energy consumption, criteria air pollutants and greenhouse gases (carbon emissions) have been charted in Figures 2 through 9 and are discussed below. Detailed results for each scenario are included in Attachment B.

4.1 Net Cost

The cost modeled by the MSW DST is consistent with "full cost accounting" principles. It includes the capital, operating and maintenance, and labor costs over the life of the facilities included in each scenario. Therefore, the cost is not necessarily representative of the tip fee charged by any facility. For facilities recover energy and/or materials and sell them to create revenue, this revenue stream is netted out of the cost. The cost results therefore represent a net annual cost.

Figure 2 shows the annual net cost results for the scenarios analyzed. In general, the cost remain relatively constance until 2009 when the WTE plant is assumed to come on-line. From 2009 to 2013, the cost increases due to the increase in waste being managed via WTE versus the other options. It should be noted that the costs represent generic average costs. Recycling is about $23/ton, compost $17/ton, WTE $87/ton, and landfill approximately $27/ton. Actual cost for specific facilities in St. Croix need to be analyzed further.

Table 4. Summary Level Results.

Parameter	**Units**	**Current**	**2007**	**2009**	**2013**
Cost	$US	6,813,783	6,916,163	9,139,335	10,308,399
Energy Consumption	MBTU	-33,876	-345,987	-1,747,154	-2,206,606
Air Emissions					
Total Particulate Matter	lb	1,423	-17,274	-85,186	-106,602
Nitrogen Oxides	lb	70,204	78,909	57,835	49,902
Sulfur Oxides	lb	5,462	-3,960	-288,656	-422,187
Carbon Monoxide	lb	9,265	-37,172	-187,362	-222,060
Carbon Dioxide Biomass	lb	25,347,551	34,076,904	90,882,949	121,403,561
Carbon Dioxide Fossil	lb	1,150,886	-2,579,842	-44,622,760	-61,829,832
Carbon Equivalents	tons	9,588	8,229	-1,694	-7,500
Hydrocarbons (non CH4)	lb	6,110	-11,667	-154,136	-212,682
Lead	lb	1	4	7	6
Ammonia	lb	-5	1,543	1,066	-2,118
Methane	lb	3,293,513	2,877,860	1,332,347	325,064
Hydrochloric Acid	lb	234	258	11,669	17,740
Ancillary Solid Waste	lb	-155,466	-1,137,998	-4,793,999	-5,609,343
Water Releases					
Dissolved Solids	lb	200	13,079	-39,851	-61,229
Suspended Solids	lb	192	4,586	2,187	3,918
BOD	lb	25,423	25,990	17,312	11,765
COD	lb	69,836	90,109	80,559	83,506
Oil	lb	21,334	18,710	8,054	1,152
Sulfuric Acid	lb	4	48	-98	-257
Iron	lb	43	213	351	526
Ammonia	lb	733	1,421	1,157	1,525
Copper	lb	0	1	2	2
Cadmium	lb	0	2	2	3
Arsenic	lb	0	0	0	0
Mercury	lb	0	3	6	0
Phosphate	lb	-3,045	-10,710	-18,166	-15,272
Selenium	lb	0	0	0	0
Chromium	lb	0	1	-1	-2
Lead	lb	0	4	7	10
Zinc	lb	-101	-366	-621	-532

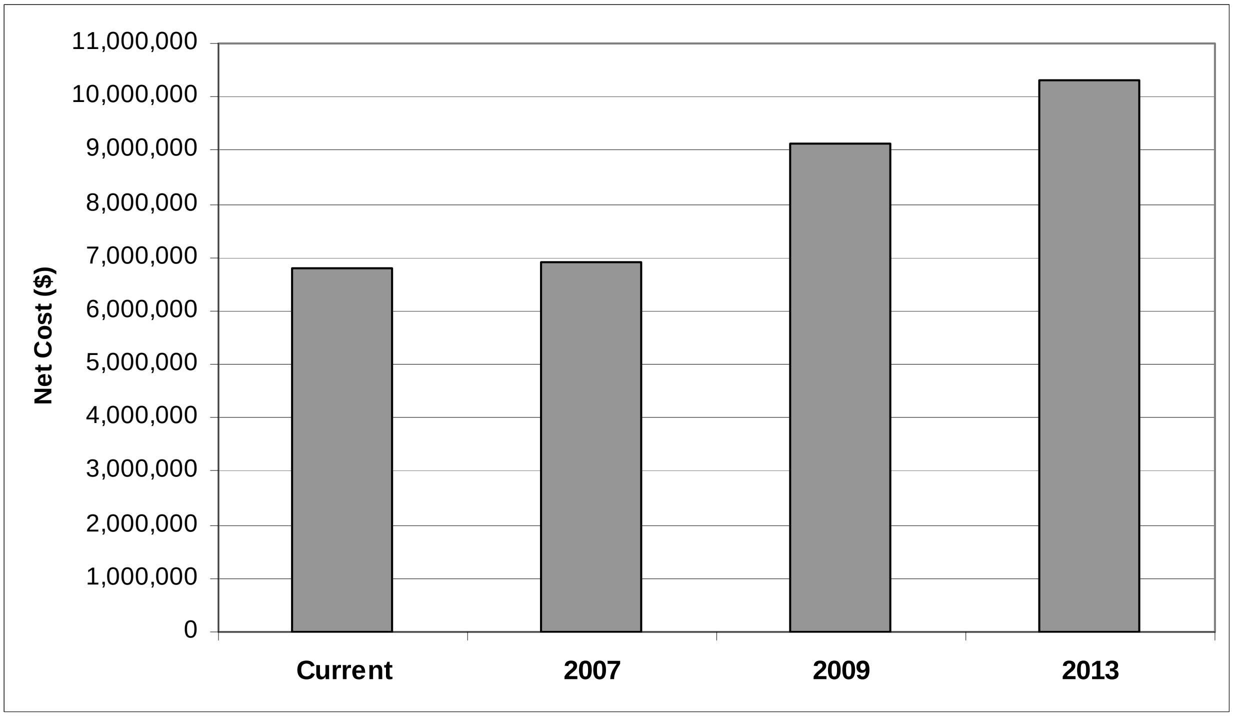

Figure 2. Net Cost by Scenario.

4.1 Net Energy Consumption

Energy is consumed by all waste management activities (e.g., landfill operations), as well as by the processes to produce energy and material inputs (e.g., landfill liner) that are included in the analysis. Energy is also produced by some waste management activities (e.g., WTE) and can be offset or avoided by others (e.g., recycling). If the energy produced/offset by the waste management system is greater than the energy consumed, then energy is saved. The benefit of this savings is that fossil fuels are saved. Energy use (or savings) is an important parameter in life-cycle studies, because it often drives the results of the study due to the significant amounts of air and water emissions associated with energy production.

As shown in Figure 3, all of the scenarios analyzed result in net energy savings. The net energy savings result from the scenarios can be summarized as resulting from the following key aspects:

- Materials recovery and recycling offsets the consumption of energy otherwise needed to extract and process virgin materials.
- Electrical energy production (via WTE) offsets the electrical energy produced in the utility sector.

The 2009 and 2013 that include WTE resulted in the largest energy savings, as one would expect.

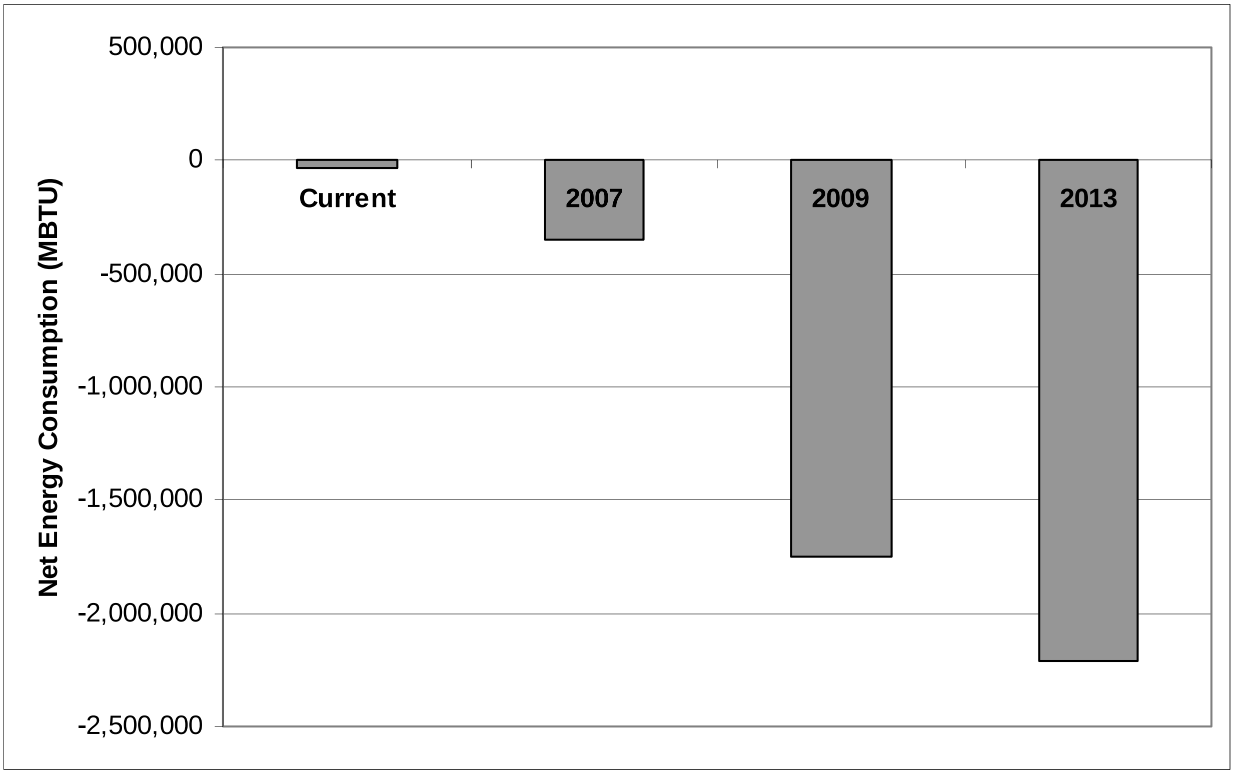

Figure 3. Net Energy Consumption by Scenario.

4.2 Criteria Pollutants

Figures 4 through 8 illustrates the results of the different management alternatives with respect to emissions of criteria air pollutants, including particulate matter, sulfur oxides, nitrogen oxides, carbon monoxide, and lead. Because criteria pollutants are highly correlated to energy and materials production, the differences in criteria pollutants generally tend to track with the differences in net energy consumption and amount of material recycled between the alternatives. On a life-cycle basis, transportation is a relatively insignificant factor when compared to energy and materials production.

4.2.1 Particulate Emissions

Particulate matter, or PM, is the term for particles found in the air, including dust, dirt, soot, smoke, and liquid droplets. Particles can be suspended in the air for long periods of time. They come from a variety of sources and, in the case of waste management and this study, result largely from fuels combustion in vehicles, combustion of waste, and combustion of fuels for the production of electrical energy. PM is a major source of haze that reduces visibility, can cause erosion of structures, and can lead to health effects associated with lung and heart disease.

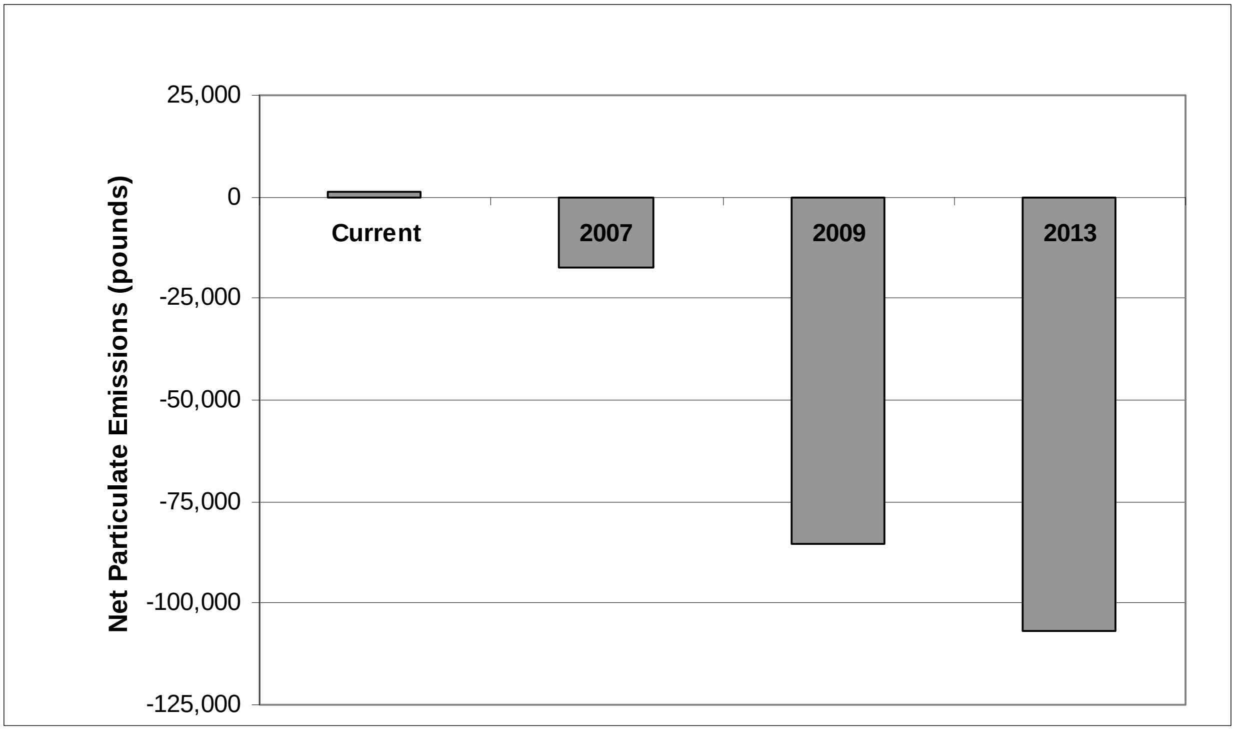

Figure 4. Net Total Particulate Matter Emissions by Scenario.

As shown in Figure 4, all but the current scenario results in a net PM offset, which means a greater amount of PM emissions are avoided that are created by virtue of materials and/or energy recovery. The 2009 and 2013 scenarios result in the largest offset of PM emissions, due to the large amount of electrical energy produced and the subsequent displacement of oil-fired power in the utility sector.

4.2.2 Nitrogen Oxide Emissions

NOx emissions can lead to such environmental impacts as smog production, acid deposition, and decreased visibility. NOx emissions are largely the result of fuel combustion and typically are largest for waste collection activities. Offsets of NOx emissions can result from the displacement of energy production and/or the recycling of materials (which also saves energy).

Figure 5 shows that significant levels of NOx emissions are produced in the current and 2007 scenarios. These emissions are all largely driven by waste collection. Emissions increase in 2007 due to the addition of organics collection and composting activities. NOx emissions are reduced in the 2009 and 2013 scenarios due to the addition of WTE and the associated offset of NOx emissions from oil-fired power in the utility sector.

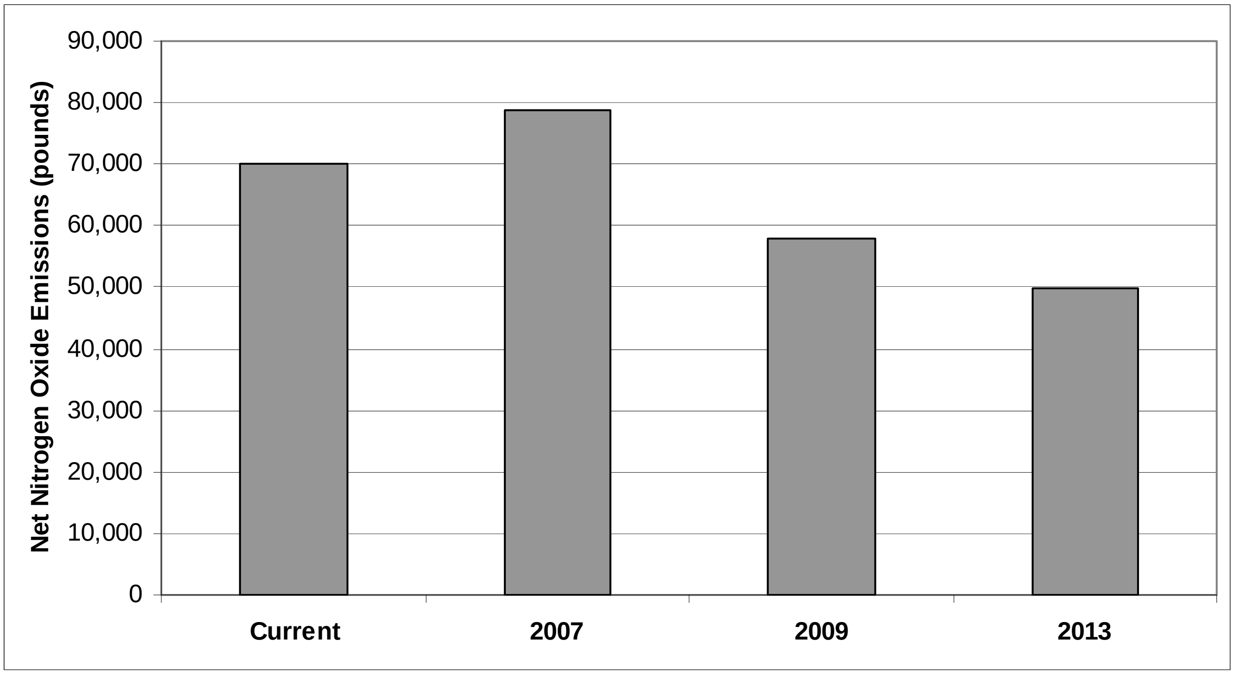

Figure 5. Net Total Nitrogen Oxide Emissions by Scenario.

4.2.3 Sulfur Oxide Emissions

SOx emissions can lead to such environmental impacts as acid deposition, corrosion, and decreased visibility. Similar to NOx emissions, SOx emissions are largely the result of fuel combustion processes. Likewise, SOx emission offsets can result from the displacement of combustion activities, mainly fuels and electrical energy production, as well as the use of lower sulfur-containing fuels.

Figure 6 shows that the current and 2007 scenarios resulted in negligible SOx emission or net offsets of SOx emissions, due primarily to the recycling activities and associated benefits offsetting SOx from waste collection and other operations. The 2009 and 2013 scenarios exhibit larger offsets of SOx due primarily to energy recovery and the large offset of SOx emissions from the combustion of oil-fired power in the utility sector.

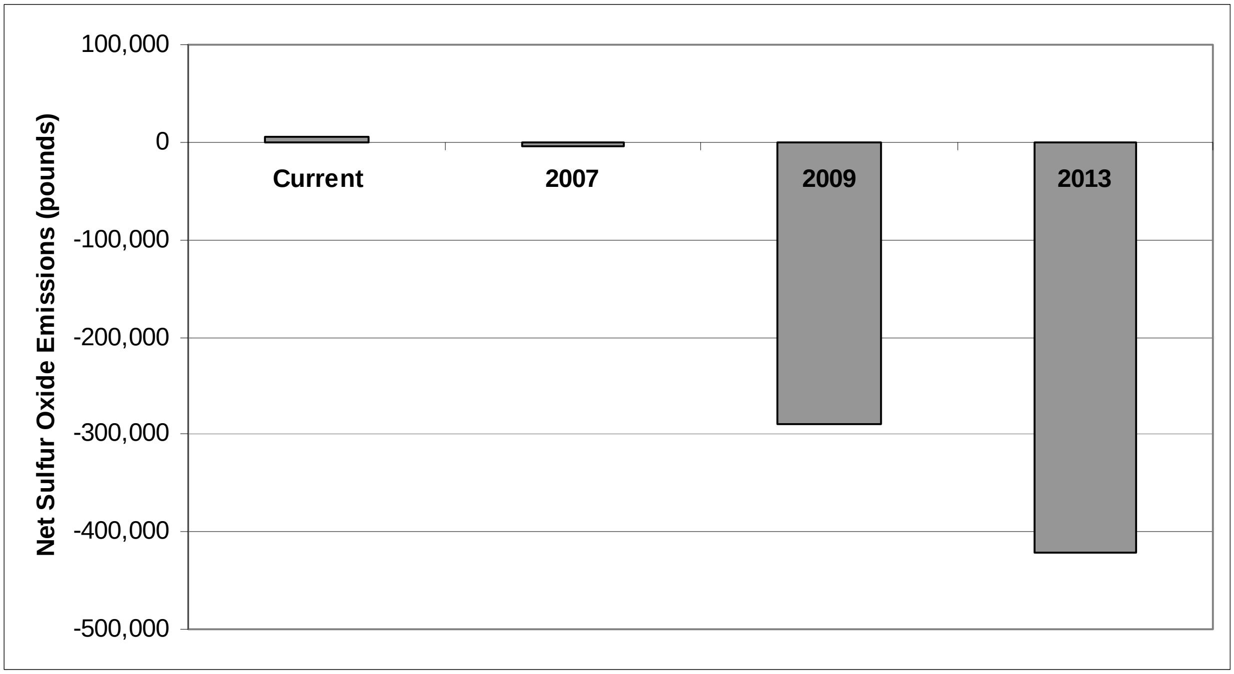

Figure 6. Net Total Sulfur Oxide Emissions by Scenario.

4.2.4 Carbon Monoxide Emissions

CO is a colorless, odorless gas that is formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust, which contributes about 56% of all CO emissions nationwide. Other sources of CO emissions include industrial processes (such as metals processing and chemical manufacturing) and power production. CO contributes to the formation of smog, which can trigger serious respiratory problems.

Figure 7 illustrates that CO follows the same trend as seen in the PM, NOx, and SOx emissions; that is, the greater the level of recycling and energy recovery, the lower the CO emissions (or greater the CO emissions offset).

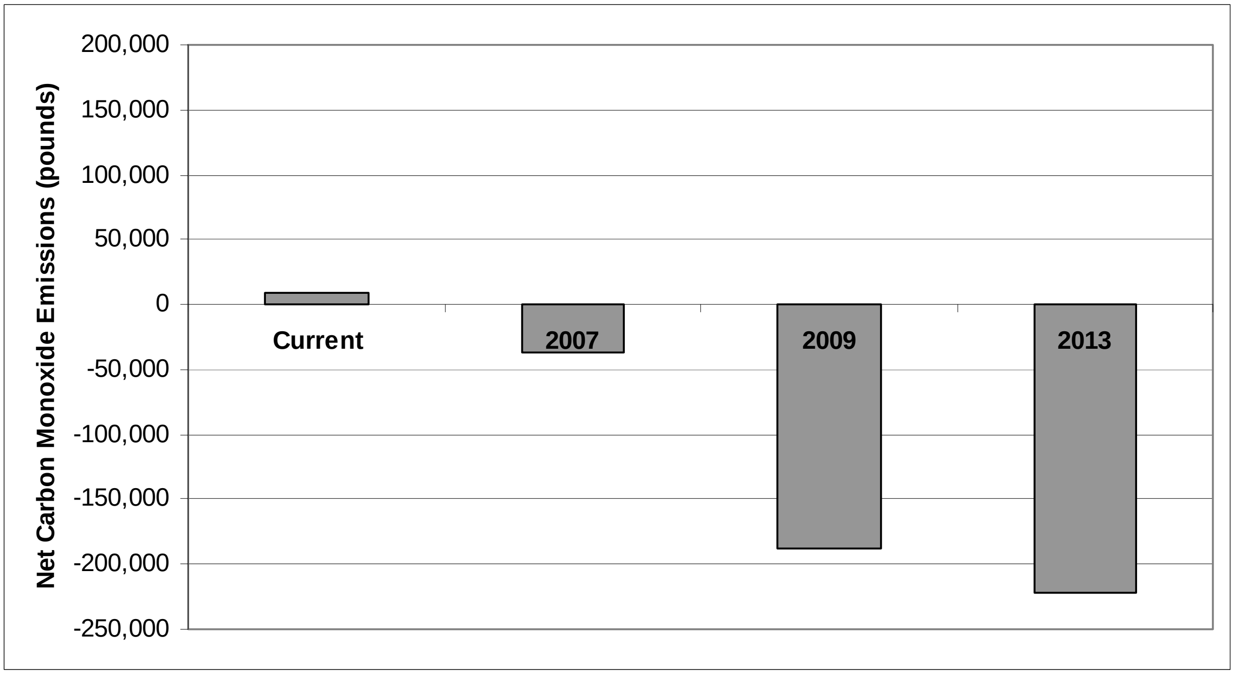

Figure 7. Net Total Carbon Monoxide Emissions by Scenario.

4.2.5 Lead Emissions

The major sources of lead emissions have historically been motor vehicles (such as cars and trucks) and industrial sources. Due to the phase-out of leaded gasoline, metals processing is the major source of lead emissions to the air today. The highest levels of lead in air are generally found near lead smelters. Other stationary sources are waste incinerators, utilities, and lead-acid battery manufacturers. People, animals, and fish are mainly exposed to lead by breathing and ingesting it in food, water, soil, or dust. Lead accumulates in the blood, bones, muscles, and fat, leading to a variety of health effects. Infants and young children are especially sensitive to even low levels of lead.

As shown in Figure 8, lead emissions increase in moving from the current scenario to the 2009 scenario. This is due to the increase in ferrous metal recycling over the years. The remanufacturing process for steel produces lead emissions. The energy recovery from the WTE process, however, offsets oil-fired power production which also produces lead emissions. Therefore, as more waste is sent to WTE in 2013, the electrical energy produced offsets more oil-fired power and thus more lead emissions.

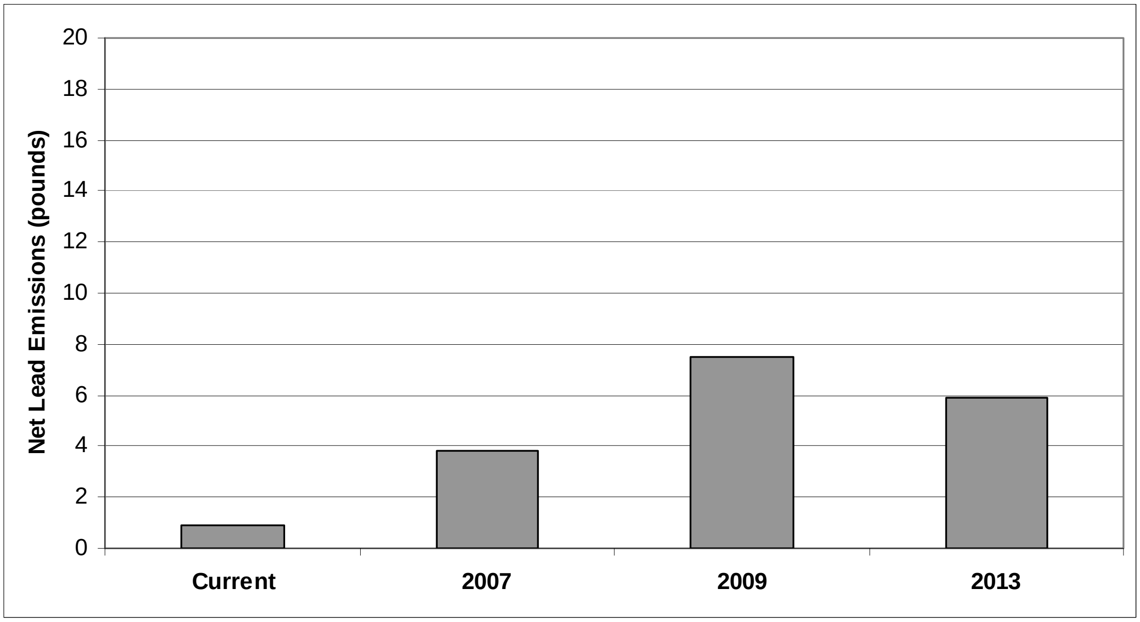

Figure 8. Net Total Lead Emissions by Scenario.

4.3 Carbon Emissions

Carbon emissions contribute to the greenhouse effect; thus, these emissions can lead to climate change and its associated impacts. Carbon emissions can result from the combustion of fossil fuels and the biodegradation of organic materials (e.g., methane gas from landfills). Offsets of carbon emissions can result from the displacement of fossil fuels, materials recycling, and the diversion of organic wastes from landfills. We report carbon emissions in units of tons of carbon equivalents, derived as follows:

$$[(\text{Fossil } CO2*1 + CH4*23)*12/44] / 2000$$

As shown in Figure 9, the WTE scenario (4) alternative results in the largest net offset of carbon emissions. This offset is directly related to the following aspects:

- Electrical energy production offsets carbon emissions from the generation of electrical energy using fossil fuels in the utility sector.
- Materials recovery and recycling offsets carbon emissions by avoiding the consumption of electrical energy generated by fossil fuels.
- Landfill disposal, which creates methane gas, a potent GHG, is avoided.

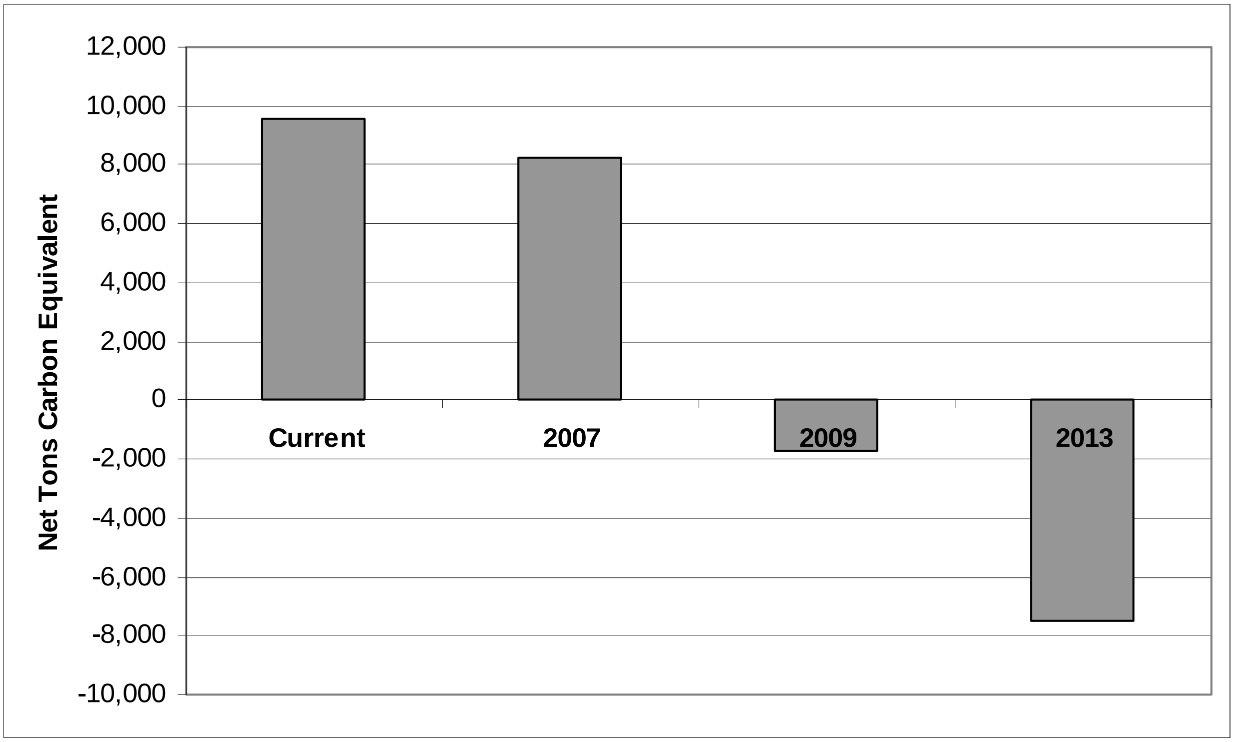

Figure 9. Net Total Carbon Equivalent Emissions by Scenario.

Moving from the current to 2007 scenario illustrates the impact of increasing the recycling rate by 2.5 percent (to 5 percent in 2007) and adding minimal levels of composting on carbon emissions. Moving from the 2007 to 2009 and 2013 scenarios illustrates the impact that adding WTE into the waste management scheme has on carbon emissions. In general, in moving from the current scenario to the 2013 scenario, more waste is diverted from the landfill and more materials and energy are recovered. Each of these aspects contributes to the improvement in carbon emissions.

5.0 Conclusions

The results of this analysis were useful for identifying the potential cost and environmental implications of the predefined MSW management scenarios and to demonstrate tradeoffs exist between cost and environmental aspects. In general, it appears that the higher the materials and energy recovery the better the environmental performance. However, increasing recycling rates by 25-30 percent is very difficult as seen in other cities and regions with mature recycling programs. The current and 2007 scenarios that didn’t include WTE were the cheapest, but generally lower environmental performers.

The results presented in this report should be used as general indicators since they represent process averages. Analyses of specific technologies or facilities may produce different results.

Attachment A
Background Information About the MSW DST

The MSW DST was developed through a cooperative agreement between the U.S. EPA's Office of Research and Development and RTI's Center for Environmental Analysis to assist communities and other waste planners in conducting cost and environmental modeling of MSW management systems. Users can evaluate the numerous MSW management strategies that are feasible within a community or region and identify the alternatives that are economically and environmentally efficient, making tradeoffs if necessary.

The MSW DST allows users to analyze existing waste management systems and proposed future systems based on user-specified information (e.g., waste generation levels, waste composition, diversion rates, infrastructure). The current components included in the MSW DST are waste collection, transfer stations, material recovery facilities (MRFs), mixed MSW and yard waste composting, combustion and refuse-derived fuel production, and conventional or bioreactor landfills. Existing facilities and/or equipment can be incorporated as model constraints to ensure that previous capital expenditures are not negated by the model solution.

As illustrated in Figure 1-1**,** the MSW DST consists of several components, including process models, waste flow equations, an optimization module, 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 coefficients on a per unit mass basis for each of the 39 MSW components being modeled for each solid waste management unit process (collection, transfer, etc.). Each process model describes and represents the essential activities that take place during the processing of waste items. For example, the collection model includes parameters for waste collection frequency, collection vehicle type and capacity, number of crew members, and number of houses served at each stop. Although national average default values are included in the MSW DST for such parameters, users can override the default values with site-specific information. These operational details, which are input by the user to represent an MSW management system, are then synthesized in the process model to estimate the cost of processing as a function of the quantity and composition of the waste entering that process. The resulting cost coefficients from each waste management process model are then used to estimate the cost of that option.

The MSW DST also contains models for ancillary processes that may be used by different waste management processes. These models calculate emissions for fuels and electrical energy production, materials production, and transportation. Electricity, for example, is used in every waste management process. Based on the user-specified design information and the emissions associated with generating electricity from each fuel type, the MSW DST 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, MRFs use electricity for conveyors and facility lighting. The emissions associated with electricity generation would be assigned to the mass that flowed through that facility. Users can specify whether the emissions associated with generating electrical energy are based on a national, regional, or user-defined mix of fuel.

The optimization module is implemented using a commercial linear programming solver called CPLEX. 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 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.

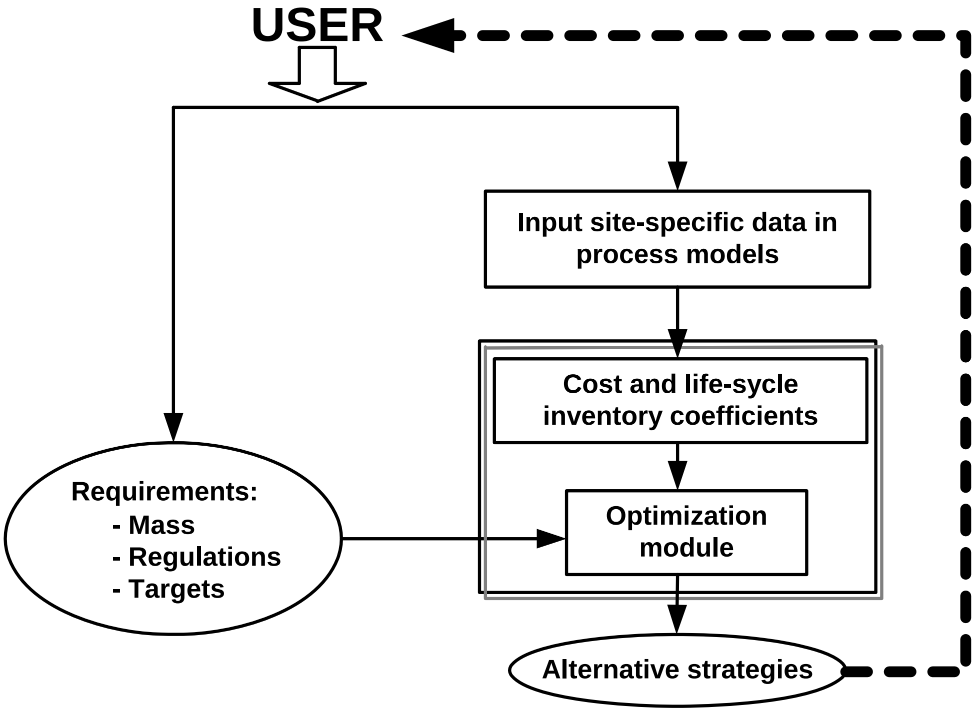

Figure 1-1. Conceptual Framework for the MSW DST.

The environmental aspects associated with a defined MSW management strategy are estimated in terms of annual net cost, energy consumption, and environmental releases (air, water, solid waste). For example, waste collection vehicles consume fuel and release several types of air pollutants in their exhaust. The collection process model of the MSW DST uses information about the quantity and composition of waste generated and a host of collection route parameters to estimate the amount of fuel consumed and air emissions by waste constituent collected. In addition, the environmental burdens associated with producing the fuel used in the collection vehicles are calculated and included in the collection results. All process modules in the MSW DST operate in a similar manner and express results as a function of the quantity and composition of the waste entering each process.

In some waste management processes, cost, energy, and emission offsets may occur. For example, diverting recycling materials from the waste stream results in a revenue stream and can displace energy consumption and emissions associated with virgin materials production. Similarly, waste management processes that recover energy (e.g., WTE, landfill gas utilization) will displace energy production in the utility sector and thereby avoid fossil fuel production- and combustion-related emissions. In applying the MSW DST, any materials or energy recovery-related benefits are netted out of the results for each process.

Attachment B
Detailed Scenario Results

Current Scenario Details

Parameter	Units	Total	Collection	Recycling	Landfill	Transport	Remfg Offset
Cost	US$	6,813,783	3,549,972	60,536	3,253,876	1,650	-52,250
Energy Consumption	MBTU	-33,876	27,300	619	56,479	162	-118,435
Air Emissions							
Total Particulate Matter	lb	1,423	700	276	8,492	32	-8,077
Nitrogen Oxides	lb	70,204	57,307	847	13,838	223	-2,012
Sulfur Oxides	lb	5,462	4,465	1,307	3,323	63	-3,697
Carbon Monoxide	lb	9,265	9,352	140	18,160	220	-18,608
Carbon Dioxide Biomass	lb	25,347,551	1,053	120	25,095,648	6	250,724
Carbon Dioxide Fossil	lb	1,150,886	1,346,654	208,278	1,025,396	26,041	-1,455,484
Carbon Equivalents	tons	9,588	186	30	9,572	4	-202
Hydrocarbons (non CH4)	lb	6,110	9,651	94	3,082	90	-6,807
Lead	lb	1	0	0	0	0	1
Ammonia	lb	-5	0	0	2	0	-7
Methane	lb	3,293,513	704	400	3,293,672	4	-1,268
Hydrochloric Acid	lb	234	5	15	191	0	23
Ancillary Solid Waste	lb	-155,466	23,506	38,807	137,914	136	-355,829
Water Emissions							
Dissolved Solids	lb	200	5,998	123	1,327	36	-1,286
Suspended Solids	lb	192	138	129	165	1	-102
BOD	lb	25,423	22	0	25,121	0	279
COD	lb	69,836	150	2	69,938	1	-255
Oil	lb	21,334	140	2	21,190	1	2
Sulfuric Acid	lb	4	1	2	2	0	0
Iron	lb	43	3	13	9	0	17
Ammonia	lb	733	2	0	802	0	-72
Copper	lb	0	0	0	0	0	0
Cadmium	lb	0	0	0	0	0	0
Arsenic	lb	0	0	0	0	0	0
Mercury	lb	0	0	0	0	0	0
Phosphate	lb	-3,045	1	1	6	0	-3,052
Selenium	lb	0	0	0	0	0	0
Chromium	lb	0	0	0	0	0	0
Lead	lb	0	0	0	0	0	0
Zinc	lb	-101	0	0	0	0	-102

2007 Scenario Details

Parameter	Units	Total	MSW Collection	YW Collection	Recycling	Compost	Landfill	Transport	Remfg Offset
Cost	US$	6,916,163	3,342,364	446,306	219,650	244,714	2,846,730	5,986	-189,586
Energy Consumption	MBTU	-345,987	25,703	4,308	2,248	1,492	49,412	587	-429,736
Air Emissions									
Total Particulate Matter	lb	-17,274	659	103	3,075	651	7,430	117	-29,308
Nitrogen Oxides	lb	78,909	53,956	8,003	4,744	6,589	12,107	811	-7,300
Sulfur Oxides	lb	-3,960	4,204	705	507	901	2,907	230	-13,415
Carbon Monoxide	lb	-37,172	8,805	1,322	434	3,097	15,888	799	-67,517
Carbon Dioxide Biomass	lb	34,076,904	991	166	755,727	10,454,742	21,955,516	23	909,739
Carbon Dioxide Fossil	lb	-2,579,842	1,267,900	195,934	107	245,779	897,092	94,489	-5,281,143
Carbon Equivalents	tons	8,229	175	27	340	34	8,374	13	-733
Hydrocarbons (non CH4)	lb	-11,667	9,087	0	0	921	2,696	326	-24,697
Lead	lb	4	0	0	1	0	0	0	3
Ammonia	lb	1,543	0	0	1,452	115	1	0	-25
Methane	lb	2,877,860	663	111	54	71	2,881,547	15	-4,601
Hydrochloric Acid	lb	258	4	1	0	2	167	0	84
			0	0			0		
Ancillary Solid Waste	lb	-1,137,998	22,131	3,719	0	6,108	120,658	494	-1,291,107
Water Emissions									
Dissolved Solids	lb	13,079	5,647	946	467	9,393	1,161	129	-4,665
Suspended Solids	lb	4,586	130	22	1	4,657	145	3	-371
BOD	lb	25,990	21	4	8	2,967	21,978	0	1,012
COD	lb	90,109	141	24	9	29,669	61,187	3	-924
Oil	lb	18,710	131	22	7	3	18,538	3	6
Sulfuric Acid	lb	48	1	0	46	0	1	0	0
Iron	lb	213	3	1	1	138	8	0	62
Ammonia	lb	1,421	2	0	0	976	702	0	-260
Copper	lb	1	0	0	0	1	0	0	0
Cadmium	lb	2	0	0	0	2	0	0	0
Arsenic	lb	0	0	0	0	0	0	0	0
Mercury	lb	3	0	0	3	0	0	0	0
Phosphate	lb	-10,710	1	0	0	360	5	0	-11,076
Selenium	lb	0	0	0	0	0	0	0	0
Chromium	lb	1	0	0	0	0	0	0	0
Lead	lb	4	0	0	0	4	0	0	0
Zinc	lb	-366	0	0	0	3	0	0	-369

2009 Scenario Details

Parameter	Units	Total	MSW Collection	YW Collection	MRF	Compost	WTE	Landfill	Ash Landfill	Transport	Remfg Offset
Cost	US$	9,139,335	2,989,743	816,645	372,147	447,775	3,402,899	1,337,038	79,231	15,069	-321,210
Energy Consumption	MBTU	-1,747,154	22,991	7,882	3,808	2,730	-235,888	23,207	618	1,787	-1,574,291
Air Emissions											
Total Particulate Matter	lb	-85,186	590	188	5,210	1,190	2,685	3,489	38	355	-98,932
Nitrogen Oxides	lb	57,835	48,263	14,644	8,038	12,057	-13,127	5,686	418	2,466	-20,609
Sulfur Oxides	lb	-288,656	3,760	1,290	859	1,649	-258,106	1,366	71	700	-40,244
Carbon Monoxide	lb	-187,362	7,876	2,419	736	5,667	21,087	7,462	142	2,431	-235,181
Carbon Dioxide Biomass	lb	90,882,949	887	304	1,280,403	19,129,953	58,618,029	10,311,955	7	69	1,541,341
Carbon Dioxide Fossil	lb	-44,622,760	1,134,136	358,517	182	449,723	-28,211,160	421,341	29,857	287,435	-19,092,791
Carbon Equivalents	tons	-1,694	156	49	576	62	-3,864	3,933	4	39	-2,650
Hydrocarbons (non CH4)	lb	-154,136	8,128	0	0	1,685	-76,338	1,266	107	992	-89,977
Lead	lb	7	0	0	1	0	-6	0	0	0	12
Ammonia	lb	1,066	0	0	2,460	210	-1,563	1	0	0	-43
Methane	lb	1,332,347	593	203	92	130	-5,870	1,353,390	5	46	-16,242
Hydrochloric Acid	lb	11,669	4	1	0	4	11,261	79	0	0	320
Ancillary Solid Waste	lb	-4,793,999	19,796	6,805	0	11,176	-201,598	56,670	214	1,501	-4,688,564
Water Emissions											
Dissolved Solids	lb	-39,851	5,051	1,732	791	17,188	-51,924	545	40	393	-13,667
Suspended Solids	lb	2,187	116	40	1	8,521	-3,746	68	2	9	-2,823
BOD	lb	17,312	19	6	13	5,429	-194	10,322	0	1	1,715
COD	lb	80,559	126	43	14	54,288	-1,307	28,738	212	10	-1,565
Oil	lb	8,054	118	40	11	5	-1,219	8,707	423	9	-41
Sulfuric Acid	lb	-98	1	0	78	1	-177	1	0	0	-1
Iron	lb	351	3	1	1	252	-17	4	1	0	105
Ammonia	lb	1,157	2	1	0	1,785	-21	330	1	0	-941
Copper	lb	2	0	0	0	1	0	0	0	0	0
Cadmium	lb	2	0	0	0	4	-2	0	0	0	0
Arsenic	lb	0	0	0	0	0	0	0	0	0	0
Mercury	lb	6	0	0	6	0	0	0	0	0	0
Phosphate	lb	-18,166	1	0	0	659	-89	2	0	0	-18,739
Selenium	lb	0	0	0	0	0	0	0	0	0	0
Chromium	lb	-1	0	0	0	1	-2	0	0	0	0
Lead	lb	7	0	0	0	7	0	0	0	0	0
Zinc	lb	-621	0	0	0	5	-1	0	0	0	-625

2013 Scenario Details

Parameter	Units	Total	MSW Collection	YW Collection	MRF	Compost	WTE	Landfill	Ash Landfill	Transport	Remfg Offset
Cost	US$	10,308,399	2,637,122	1,186,984	423,127	650,835	5,201,884	345,309	118,847	20,588	-276,298
Energy Consumption	MBTU	-2,206,606	20,280	11,457	4,470	3,968	-360,592	5,994	928	2,482	-1,895,591
Air Emissions											
Total Particulate Matter	lb	-106,602	520	274	1,945	1,730	4,105	901	58	493	-116,627
Nitrogen Oxides	lb	49,902	42,571	21,284	6,068	17,524	-20,067	1,469	627	3,426	-23,000
Sulfur Oxides	lb	-422,187	3,317	1,874	9,175	2,396	-394,557	353	107	972	-45,824
Carbon Monoxide	lb	-222,060	6,947	3,516	1,069	8,236	32,235	1,927	213	3,377	-279,581
Carbon Dioxide Biomass	lb	121,403,561	782	442	842	27,805,165	89,607,189	2,663,212	11	96	1,325,824
Carbon Dioxide Fossil	lb	-61,829,832	1,000,372	521,101	1,481,710	653,667	-43,125,339	108,818	44,786	399,347	-22,914,294
Carbon Equivalents	tons	-7,500	138	72	210	90	-5,906	1,016	6	55	-3,180
Hydrocarbons (non CH4)	lb	-212,682	7,169	0	721	2,449	-116,694	327	160	1,378	-108,193
Lead	lb	6	0	0	0	0	-9	0	0	0	15
Ammonia	lb	-2,118	0	0	1	305	-2,389	0	0	1	-37
Methane	lb	325,064	523	296	2,802	189	-8,973	349,533	8	64	-19,376
Hydrochloric Acid	lb	17,740	3	2	104	6	17,214	20	0	0	389
Ancillary Solid Waste	lb	-5,609,343	17,461	9,890	271,445	16,244	-308,175	14,636	322	2,086	-5,633,253
Water Emissions											
Dissolved Solids	lb	-61,229	4,455	2,517	888	24,983	-79,374	141	60	546	-15,444
Suspended Solids	lb	3,918	103	58	900	12,385	-5,727	18	2	12	-3,833
BOD	lb	11,765	17	9	2	7,891	-297	2,666	0	2	1,475
COD	lb	83,506	111	63	15	78,907	-1,997	7,422	317	14	-1,347
Oil	lb	1,152	104	59	17	7	-1,863	2,249	635	13	-68
Sulfuric Acid	lb	-257	1	1	13	1	-271	0	0	0	-1
Iron	lb	526	3	1	88	367	-26	1	2	0	91
Ammonia	lb	1,525	2	1	2	2,595	-32	85	2	0	-1,130
Copper	lb	2	0	0	0	2	0	0	0	0	0
Cadmium	lb	3	0	0	0	5	-3	0	0	0	0
Arsenic	lb	0	0	0	0	0	0	0	0	0	0
Mercury	lb	0	0	0	0	0	0	0	0	0	0
Phosphate	lb	-15,272	0	0	6	957	-136	1	0	0	-16,102
Selenium	lb	0	0	0	0	0	0	0	0	0	0
Chromium	lb	-2	0	0	0	1	-3	0	0	0	0
Lead	lb	10	0	0	0	10	0	0	0	0	0
Zinc	lb	-532	0	0	0	7	-1	0	0	0	-537