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# Moving from Solid Waste Disposal to Materials Management in the United States

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**SUMMARY:** The desire for less waste and more sustainable use of resources has resulted in the U.S. EPA's Resource Conservation Challenge. This initiative is directed towards helping the U.S. transition from waste disposal towards materials management. Understanding the potential environmental and economic tradeoffs requires the use of life-cycle analysis and full cost accounting. Using the Municipal Solid Waste Decision Support Tool (MSW-DST), nine scenarios were evaluated to compare the life-cycle environmental tradeoffs and costs for a range of technologies for a medium-size U.S. community. The MSW-DST can be used to identify more sustainable use of resources, which helps meet goals set forth in the Resource Conservation Challenge.

## 1. INTRODUCTION

The U.S. EPA initiated the Resource Conservation Challenge in 2002 to help the U.S. move from solid waste to materials management (EPA, 2003b and 2004). This is to be done through: (1) pollution prevention, recycling, and reuse of materials; (2) reduction of the use of toxic chemicals; and (3) conservation of energy and materials. The objectives are to encourage more sustainable resource use and to minimize waste.

With the transition from waste management to materials management, tools are needed that consider life-cycle environmental tradeoffs. Determining the best means to manage solid waste is not straightforward. Questions that arise include: Should food waste be composted or landfilled? Should newsprint be recycled, landfilled, or combusted? What is the environmental benefit or burden from increasing the recycling rate in a community or adopting a curb-side recycling program? Many communities face competing priorities. To address budgetary concerns, recycling programs are often targeted for reduction and even elimination, which occurred in New York City. Are there changes that could be made within existing infrastructure that could improve efficiency and reduce environmental burdens and cost?

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A decision support tool (DST) has been developed by the RTI International and its partners (including North Carolina State University and the University of Wisconsin) in collaboration with EPA's National Risk Management Research Laboratory (NRMRL). (Thorneloe, et al., 1999a, 2001 and 2003) This tool provides a standard approach for evaluating the life-cycle environmental tradeoffs and full costs of solid waste management. The types of questions that the MSW DST answers are identified in Figure 1. The analysis calculates life-cycle environmental burdens for all waste management activities including collection, transportation, material recovery facilities, transfer stations, composting, remanufacturing (of recovered materials), landfilling, and combustion, as well as off-sets for the potential benefits from conservation of energy and materials. Since the development of the MSW-DST, over 35 applications of the tool have been conducted on the community, state, and national levels, including use of the tool to help evaluate waste conversion technologies for the State of California (Jambeck et al., 2005; Thorneloe et al, 2001, 2003, 2004). The tool is currently being updated and will be web-accessible in 2006 to provide easier access to users.

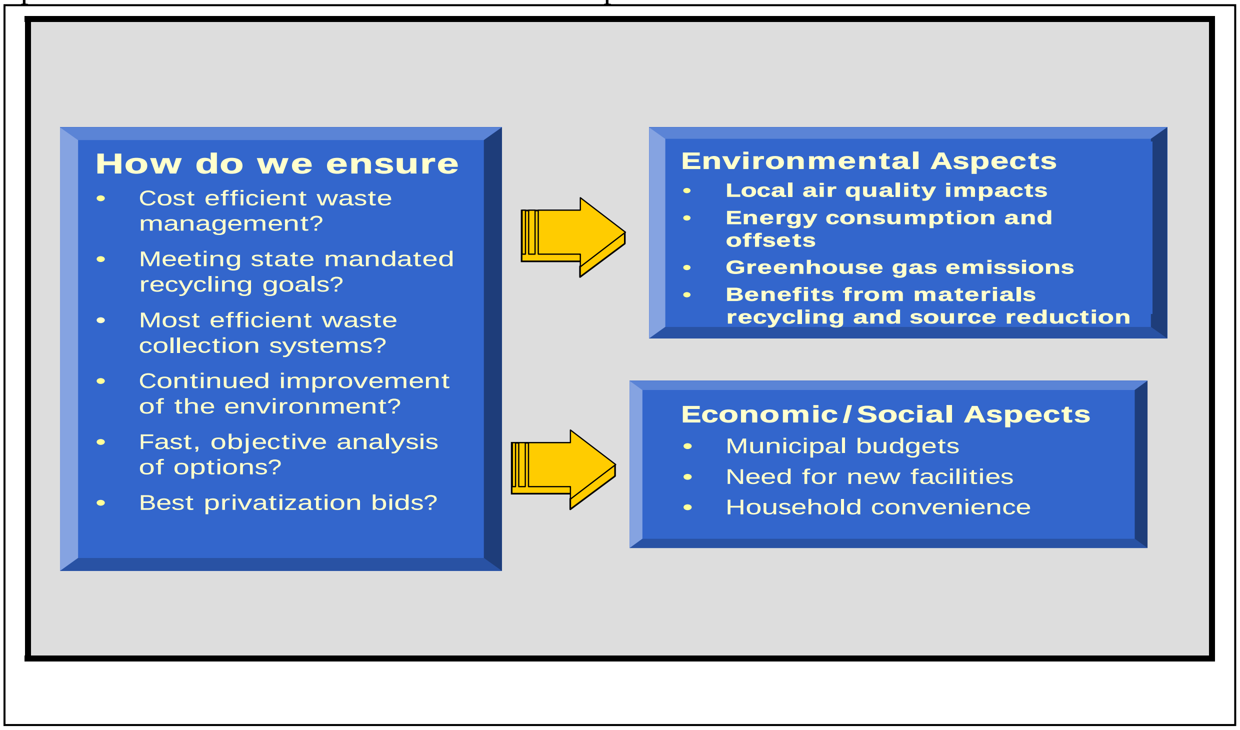

**Figure 1. Types of Questions Addressed by the MSW Decision Support Tool**

Although recycling can often have significant environmental benefits, there are differences in the level of environmental benefits depending upon the type of material (i.e., aluminum cans, glass, newspaper, plastic bottles, and steel cans), the remanufacturing process, and the distance to markets or manufacturing facilities. The MSW DST provides data needed to evaluate components on an individual basis that captures differences that may occur to how the material is managed (Weitz, 2003). Through this type of analysis, communities will be able to find more sustainable solutions that minimize environmental burdens and maximize resource conservation and recovery. (Coleman et al., 2003; McDougall et al., 2001; White et al., 1995)

The objective of this paper is to illustrate how the MSW DST can be used to evaluate tradeoffs in management options for a medium size community with a population of 750,000 and a waste generation rate of approximately 1.6 kg (3.5 lbs) per person per day (EPA, 2003a). We have included analysis of waste management practices typical of the 1970s when there was limited recycling and minimal requirements for landfills. We also evaluated the range of options in use today for collection, transportation, recycling (including transfer stations and materials recovery facilities), combustion, and landfilling.

Table 1 describes each scenario in detail. These scenarios were chosen in this particular order to represent the advancement of solid waste technology and evolution of waste management in the U.S. The range of options considers increasing the recycling rate and energy recovery from landfill gas and waste combustion. Scenario 1 represents management practices typical of the 1970s. The scenario that is considered most typical of current U.S. practice is Scenario 4. However, there can be tremendous diversity between geographical regions and between urban and rural regions. Currently, the State of California is considering waste conversion technologies (Thorneloe et al., 2004).

**Table 1. Scenarios for this Study used in the MSW-DST**

| Scenario | Description |
|---|---|
| **1** | 10 percent recycling with remainder being landfilled with no landfill gas collection and control |
| **2** | Same as Scenario 1 except 20% recycling rate |
| **3** | Same as Scenario 2 except 30% recycling rate |
| **4** | Same as Scenario 3 except with landfill has gas collection and control using flare |
| **5** | Same as Scenario 4 except landfill gas is used to produce electricity using internal combustion engine |
| **6** | Same as Scenario 4 except landfill gas is piped to nearby industrial facility and combusted in boiler (displacing fuel oil). |
| **7** | Same as Scenario 3 except use of waste to energy facility (generating electricity and recovery of metals) |
| **8** | Same as Scenario 3 except waste is collected and transported to transfer station, and then long-hauled 800 kilometers (500 miles) to landfill using semi-tractor truck |
| **9** | Same as Scenario 8 except waste is long-hauled to landfill by rail |

## 2. U.S. WASTE MANAGEMENT

In the U.S., more than 208 million metric tons of municipal solid waste (MSW) was generated in 2000 and more than $40 billion dollars was spent on its management. Figure 2 provides U.S. trends in MSW generation (http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm) since the 1960s (EPA, 2003a). The composition of municipal solid waste prior to materials removal for recycling is provided in Figure 3. The recycling rates for the U.S. and recycling percentage for selected materials are provided in Figures 4 and 5. The RCC is targeting all sectors to determine what can be done to improve energy conservation through voluntary measures. The waste generation and recycling rates for scenarios 3 through 9 are consistent with the U.S. average.

The U.S. has made major progress in increasing recycling rates. However, the choices to be made in the future are becoming more complex and material specific such as waste conversion technologies and wet waste recycling programs. For example, communities with air quality concerns will need to factor in emissions resulting from waste collection and transport. Transitioning to materials management requires a more complete understanding of the tradeoffs to ensure that the goals of the RCC are being successfully met.

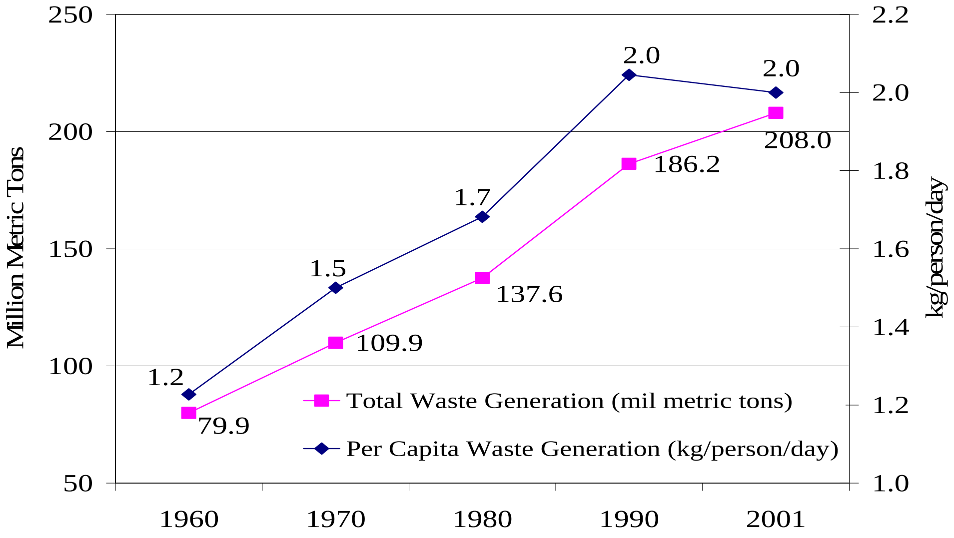

**Figure 2. Trends in U.S. MSW Generation (EPA, 2003a)**

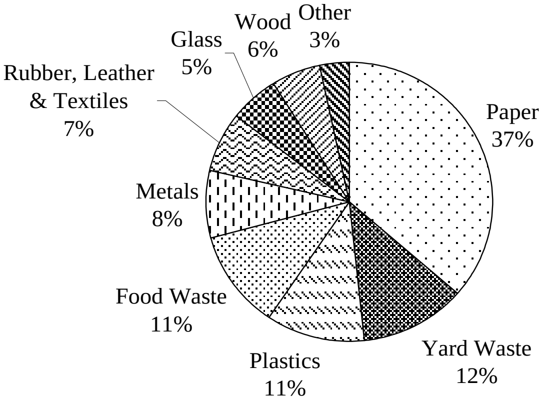

**Figure 3. 2001 U.S. Waste Generation and Characterization – 208 million metric tons (before recycling) (EPA 2003a)**

## 3. EVALUATION OF SCENARIOS USING MSW-DST

### 3.1 Description of Scenarios

For this analysis, we used the same quantity of solid waste for each scenario (437,000 metric tons/year), which represents a medium-sized community in the U.S. Weekly waste/recyclable pick-up was assumed, which is typical in the U.S., with all items collected on the same day. The modeled waste is from both residential (including multi-family dwellings) and commercial sectors. Costs were calculated using model defaults, which represent national averages.

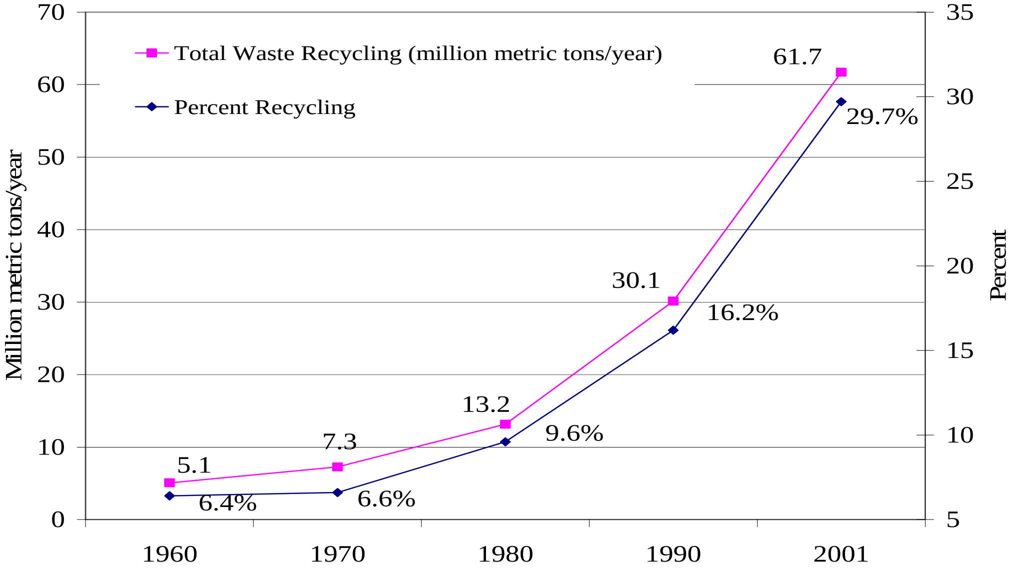

**Figure 4. U.S. Waste Recycling Rates 1960-2001 (EPA 2003a)**

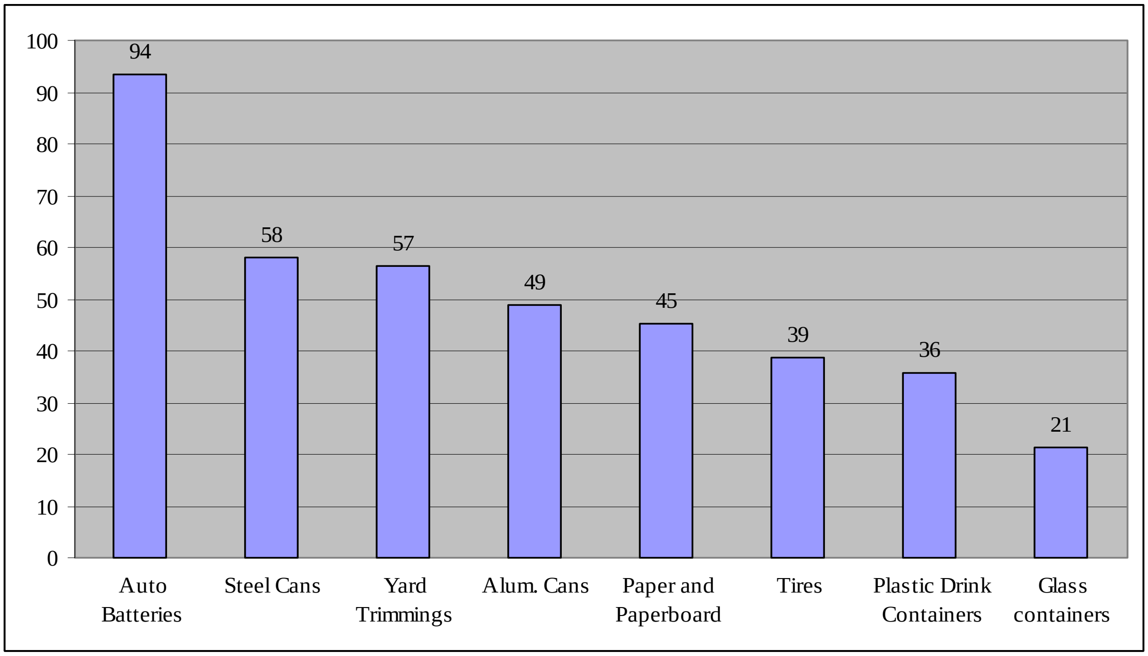

**Figure 5. Percentage of Selected Materials in the U.S. that is Recycled (EPA 2003a)**

The diversion rates in each scenario were met through a combination of recycling and yard waste composting. The MSW-DST uses linear optimization software to find the most efficient solution based on cost or environmental parameters [i.e., energy consumption, waterborne pollutants, or emissions of greenhouse gases (GHG), nitrogen oxides (NOx), particulate, and volatile organic compounds] (Solano et al., 2002a and 2002b). For this analysis, cost was used in identifying which mix of components would meet the diversion goals set in each scenario (i.e., we solved for the least cost mix that would meet the scenario goals). The analysis did not try to maximize resource conservation and recovery although this has been done in previous publications (Barlaz et al., 1999b; Harrison, 2001).

The mix of materials that were captured by the 10, 20, and 30 percent goals is presented in Figure 6. The 10 percent diversion rate was met by using recycling only (i.e., no yard waste composting). The recycling consisted of commingled recyclables from residential and multi-family housing and presorted recyclables from commercial entities. To reach the 20 and 30 percent diversion rates, the model included both recycling and yard waste composting from the residential sector.

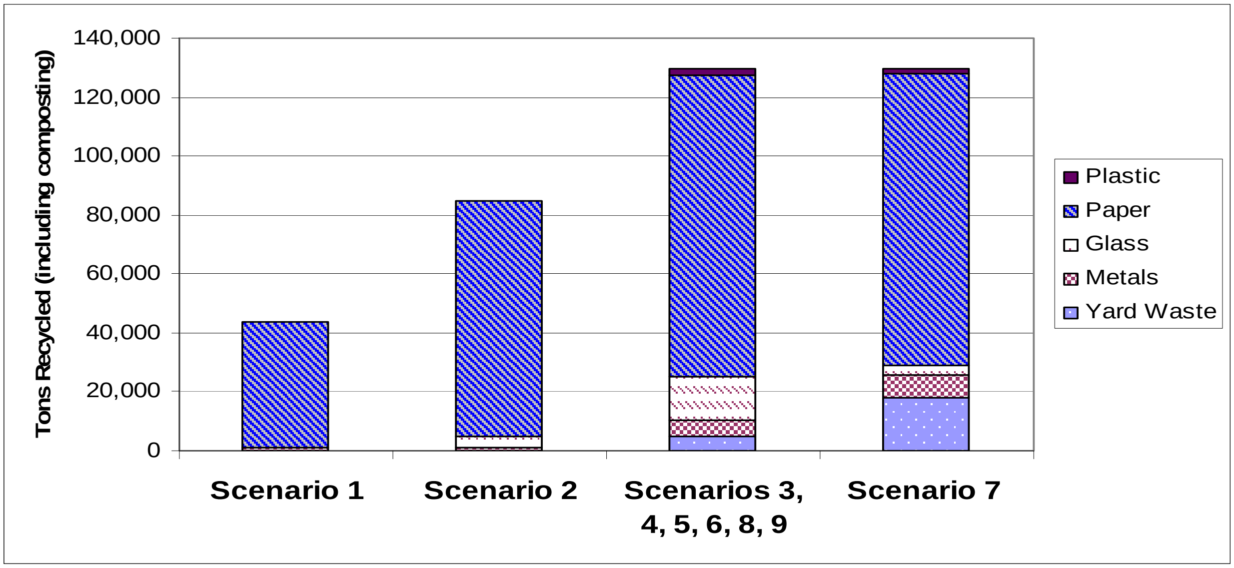

Figure 6. Composition of Materials Captured by Tonnage for Management Scenarios

Modeling of energy has been found to have a significant impact on the life-cycle environmental tradeoffs (Finnveden et al., 2002). Assumptions regarding landfill gas control can also have a significant impact (Ecobalance, 1999; Barlaz et al., 1999a). For the scenarios with landfill gas control (i.e., Scenarios 4, 5, 7, 8, 9), a landfill gas collection efficiency of 75% was assumed which is consistent with EPA's guidelines for developing emission inventories (EPA, 1997). The energy offsets that were used for Scenarios 5 and 7 are for coal combustion. In the U.S. the marginal energy source to be displaced is typically coal-fired power plants (Weitz et al., 2002) For Scenario 6, the most likely offset is fuel oil which was used in calculating the energy offset. A description of how the waste management processes are modeled has been provided in previous publications (Barlaz et al., 1999 a and b; Ham and Komolois, 2003; Harrison et al., 2001; Thorneloe and Weitz, 2001 and 2003; and Weitz, 2003).

## 3.2 Results and Discussion

Although the MSW-DST provides data on other media and pollutants, this paper focuses on a comparison of GHGs, energy consumption, nitrogen oxide emissions, and cost. The full results are being provided in a more expanded journal article to be published later this year.

The results for the net GHG emissions and energy consumption are provided in Figures 7 and 8. Previous research shows that as waste management technologies have evolved, GHG emissions have been reduced (Weitz et al, 2002). This study shows similar results. The first three scenarios illustrate recycling benefits increasing from 10 to 30% recovery. The transition between scenarios 3 and 4 quantifies the significance of landfill gas control. Most large landfills in the U.S. (i.e., greater than 2.5 million tons of waste) collect and control landfill gas. About 300 U.S. landfills have energy recovery (Thorneloe et al., 2001). The most attractive scenario from a GHG perspective is Scenario 7 which indicates a negative value due to energy offsets.

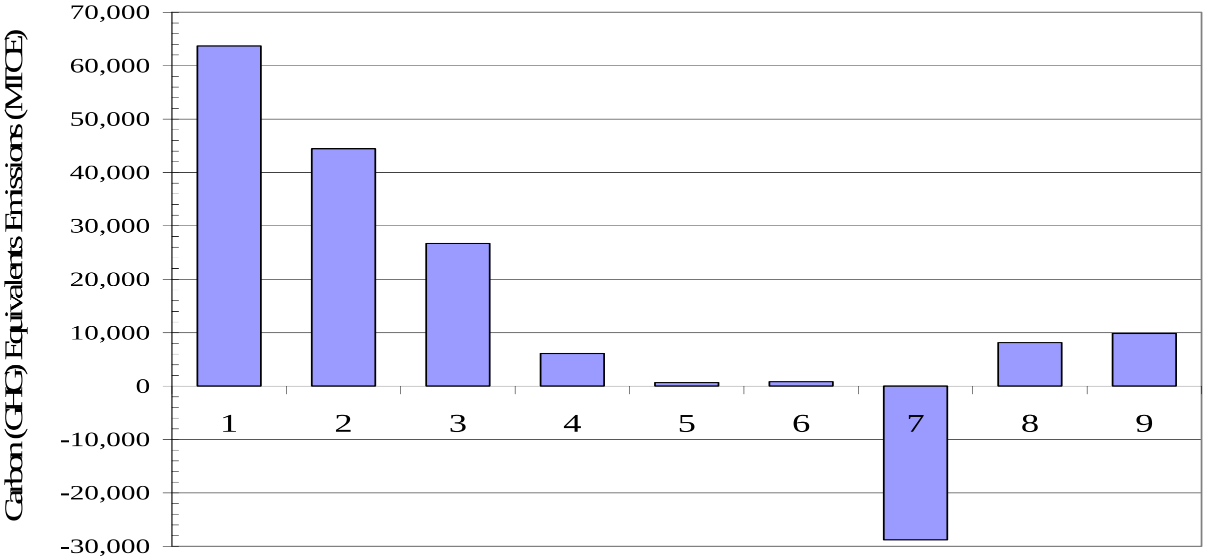

**Figure 7. Net GHG Emissions by Scenario (Million Metric Tons of Carbon Equivalents)**

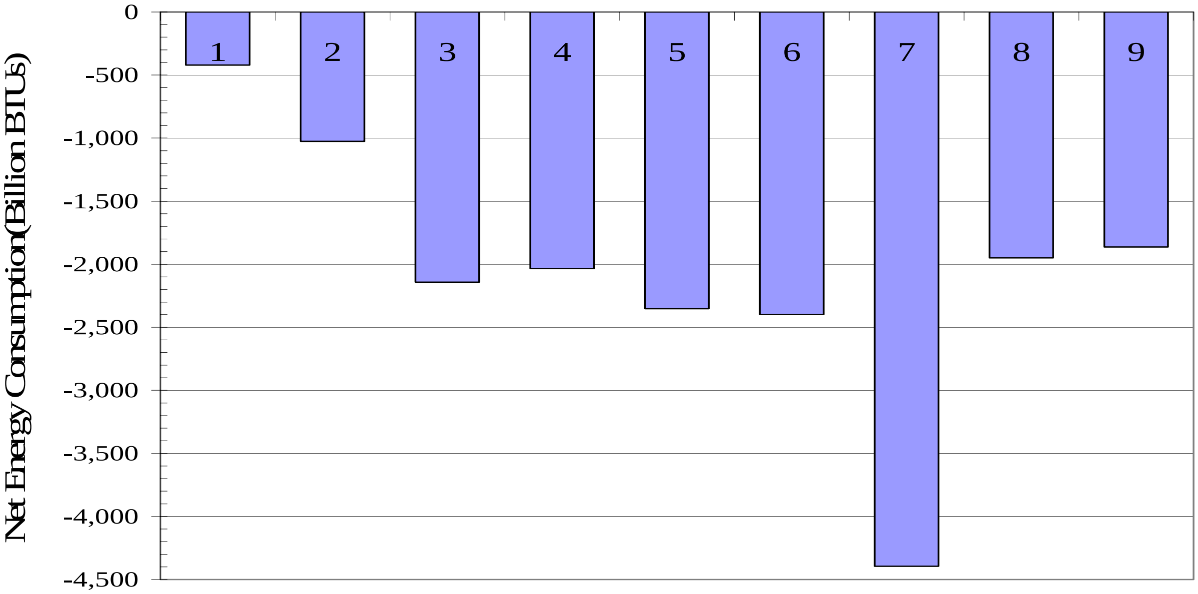

**Figure 8. Net Energy Consumption by Scenario (Billion BTUs)**

What is recycled or composted can change with significant changes in system design. For example, in the combustion scenario (7), recovery of metals from combustion ash becomes a more cost-effective recycling method and displaces diversion than what was otherwise being met by composting (i.e., metals recovery went up and composting went down). This suggests that recycling (and resulting revenue) is more cost effective than composting (based on the use of the MSW DST defaults).

The last two scenarios (i.e., 8 and 9) show the impact of long hauling using either semi-tractor trailers or rail. In the U.S., there is an increasing trend towards transporting waste over long-distances (typical distances of 480 to 800 km (300 to 500 miles), as the smaller, near-by landfills reach capacity. For those communities using long-haul transport, a transfer station is built to package the waste for long hauling using either semi-tractor trailers or rail. For the rail-haul, there is a transfer station at both ends of the rail line. For this scenario, a long-haul distance of 800 km (500 miles) was assumed. There appears to be only a slight increase in GHG emissions for long-haul transport.

Figure 9 provides results for emissions of NOx which results from combustion processes (associated with energy consumption and production). All scenarios show negative values because offsets from recycling and resource conservation are reflected in each scenario. Scenarios 5, 6, and 7 reflect the largest negative value which indicates off-sets from resource conservation and recovery.

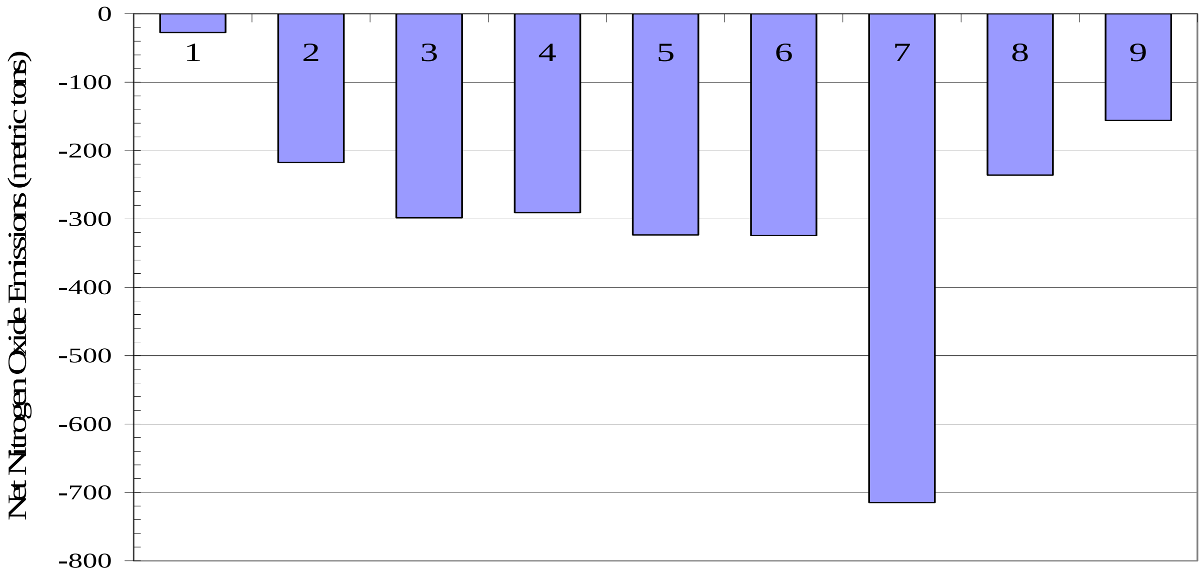

**Figure 9. Net Emissions of Nitrogen Oxides by Scenario (Metric Tons)**

Figure 10 provides the net annualized costs which includes revenue from recyclables. The lowest cost scenario is where the majority of the waste is landfilled. The highest cost scenario is where waste is long-hauled using semi-tractor diesel trucks. The second highest cost is for the waste combustion scenario which also is one of the preferred options in terms of energy consumption and emissions of GHGs and NOx.

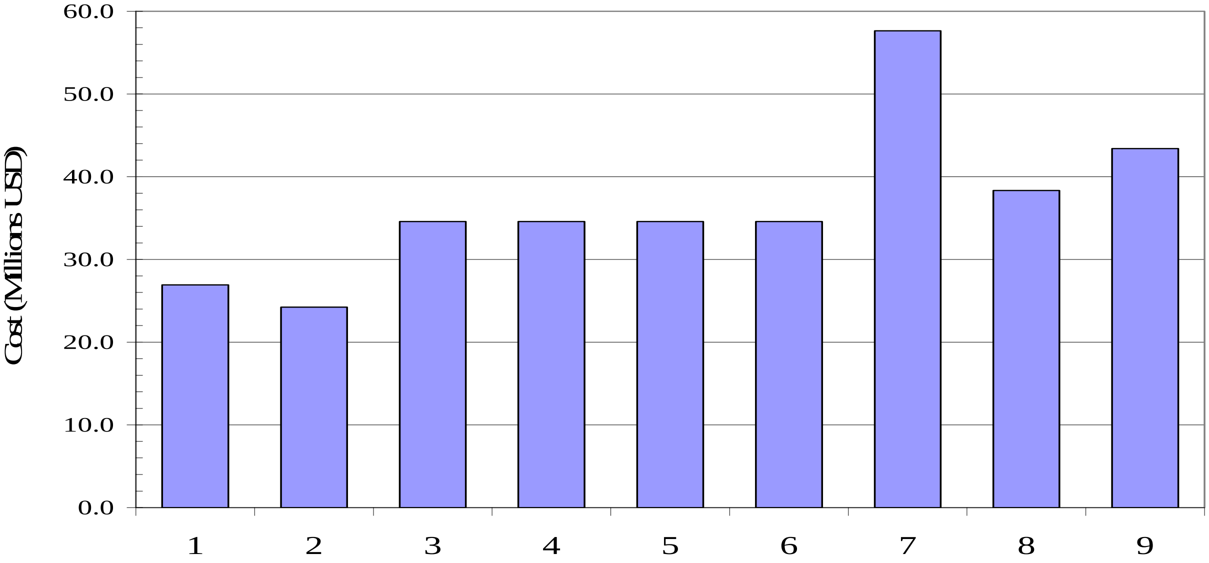

Figure 10. Net Annualized Cost of Waste Management by Scenario

## 4. CONCLUSIONS

This paper provides an evaluation of scenarios to illustrate the tradeoffs in options for solid waste management using MSW DST defaults based on national averages. Values for specific communities may be quite different depending upon site-specific values. However, the general trends are thought to be realistic. The results indicate that landfill gas control is very important in terms of GHG reductions. The combustion of waste with energy recovery appears to be an attractive option in terms of energy but less attractive in terms of cost. Long hauling of waste also has tradeoffs that need to be considered in evaluating management options.

With EPA's Resource Conservation Challenge, there is increased interest in finding more sustainable solutions for waste management. The results illustrate how there can be tremendous differences in emissions and costs among different options. What may make sense for one community may be very different for another depending upon existing infrastructure, policies, and environmental goals. This is why site-specific analyses are important in developing efficient and effective management plans.

Since the development of the MSW-DST, over 35 applications of the tool have been conducted on the community, state, and national levels, including use of the tool to help evaluate waste conversion technologies for the State of California (Jambeck et al., 2005; Thorneloe et al, 2001, 2003, 2004). In 2006, a web-accessible version of the tool is to be released which will provide easier access. We anticipate wider use of the MSW-DST once the web accessible version is available. Updates will be conducted as better data and information become available The MSW-DST will help in supporting the goals of EPA's Resource Conservation Challenge and lead towards more sustainable resource and waste management. For further information about the MSW-DST, refer to the project web site at www.rti.org (or Keith Weitz at kaw@rti.org).

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