Sustainability and Waste Management

Susan A. Thorneloe and Keith A. Weitz

Air Pollution Prevention and Control Division, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 27711, USA
Thorneloe.Susan@epa.gov

Center for Environmental Analysis, RTI International (RTI), 3040 Cornwallis Road, Research Triangle Park, NC 27709, USA. kaw@rti.org

ABSTRACT

There is a need to move toward a more sustainable use of resources. Concern for the environment and future generations is leading us to shift the focus from waste management to resource management. This paper provides an overview of a decision support tool (DST) that provides a holistic approach to waste management through more efficient and effective resource use. Three studies using the tool are presented to illustrate how the DST can be used to evaluate life-cycle environmental tradeoffs and help decision makers identify more sustainable solutions.

INTRODUCTION

In the United States (U.S.), the federal government has initiated the "Resource Conservation Challenge (RCC)" that is directed towards reducing waste (U.S. EPA, 2003). This initiative, which involves a transformation in focus from pollution prevention to materials management, was created in 2002 to find flexible, yet protective[1], ways to conserve resources through:

- Pollution prevention, recycling, and reuse of materials;
- Reduction of the use of toxic chemicals; and
- Conservation of energy and materials.

Responsibility is being shared for improving the environment through partnerships and collaborations that encourage businesses, consumers, and governments to work together to make changes across the whole supply chain – from better product design to easier product reuse and recyclability. Most of the partnerships are voluntary while others are alternatives to regulatory control. Benefits include recognition for activities that result in resource conservation. For example, manufacturers are encouraged to make products less toxic and more recyclable. They are also encouraged to prevent and reduce waste. Individuals and businesses are challenged to change their buying and disposal habits. EPA has a website that provides additional information on the Resource Conservation Challenge (www.epa.gov/rcc) including a progress report (U.S. EPA, 2004).

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[1] EPA's emphasis continues to be on the protection of human health and the environment.

Environmentally friendly design is also a component of this challenge. Buildings and products are to be designed with the goal of using fewer chemicals, increased energy efficiency, and reduced footprint. The U.S. government promotes the application of green building standards through reductions in the environmental footprint of buildings, adopting designs that conserve energy and make use of renewable sources, reducing water and waste generation, and providing a safer and cleaner indoor air environment.

The EPA is leading by example and has received awards for green building design under the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) assessment system. The EPA's facility in the Research Triangle Park, which was completed in 2002, is an example of green building. As part of the design for the EPA building, waste management was evaluated to look for opportunities to reduce waste and environmental impact. This paper provides an overview of a study that was conducted to evaluate organic waste management.

Even with greater emphasis on pollution prevention and waste reduction, there will always be waste to manage. Waste management practices have tremendously improved since the enactment of the Resource Conservation and Recovery Act (RCRA) in 1976 and amended in 1984. Uncontrolled dumping of hazardous waste has decreased dramatically. Landfill design, operation, and monitoring have greatly improved. Waste combustion facilities have stringent air pollution control and take advantage of energy recovery. There has also been a tremendous increase in post-consumer recycling rates. U.S. industries have made impressive gains in pollution prevention and reduction of toxic waste. (EPA, 2003)

With the transition from waste management to materials management, tools are needed that consider the life-cycle environmental tradeoffs. Choices on how to manage individual components that comprise solid waste are 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? Further, many communities face competing priorities and recycling programs are often targeted for reductions and even elimination which occurred in New York City. Are there things that could be done within the existing infrastructure that would improve efficiency while reducing the environmental burdens and cost?

In California, new waste conversion technologies are being considered. How do these new technologies compare to existing technologies? Do they result in more efficient resource management and energy conservation? A recent life-cycle and market impact study was conducted by RTI for the State of California comparing these new conversion technologies to existing technology. A summary of the RTI work is included in this paper as a second study.

Finally, the paper presents a national study on greenhouse gas emission trends associated with waste management. What is the impact of waste management changes on greenhouse gases since the enactment of RCRA? Data on the waste quantity, composition, and management practices were used to evaluate greenhouse gas trends over the past several decades.

EPA's Municipal Solid Waste Decision Support Tool (MSW-DST)

The EPA's National Risk Management Research Laboratory (NRMRL) began research in 1994 to develop a Municipal Solid Waste Decision Support Tool (MSW-DST). This was done in response to requests from state and local government requesting assistance on how to best manage competing resources. Over 80 stakeholders were involved, including: state and local governments; the solid waste management industry; the aluminum, glass, paper, plastics, and steel industries; environmental interest groups; trade associations; and academia. The goal was to develop a credible, objective, state-of-the-art tool that can be used to make more informed decisions regarding solid waste management (Thorneloe et al., 1999b, Barlaz et al., 1999b).

The tool was developed through a cooperative agreement (CR 823052) between EPA and RTI. The research team included North Carolina State University, who was responsible for the model structure and process model development. The research team also included the University of Wisconsin, Franklin Associates, and Roy F. Weston who were involved in the life-cycle inventory (LCI) data for composting and materials production. Through funding by the Environmental Research and Education Foundation, needed data and information were collected for developing a LCI process model for landfills. (Ecobalance, 1999, Barlaz et al., 1999a) The EPA funded laboratory studies that quantified the environmental emissions for different biodegradable components in MSW that are composted or landfilled (e.g., food waste, corrugated containers, newsprint). (Ham and Komilis, 2003; Barlaz et al., 1997) Co-funding was also provided by the U.S. Department of Energy for data collection and analysis.

NRMRL's emphasis in developing this tool was to ensure that it was based on technically-sound science and information. Figure 1 presents the type of questions that the tool was developed to

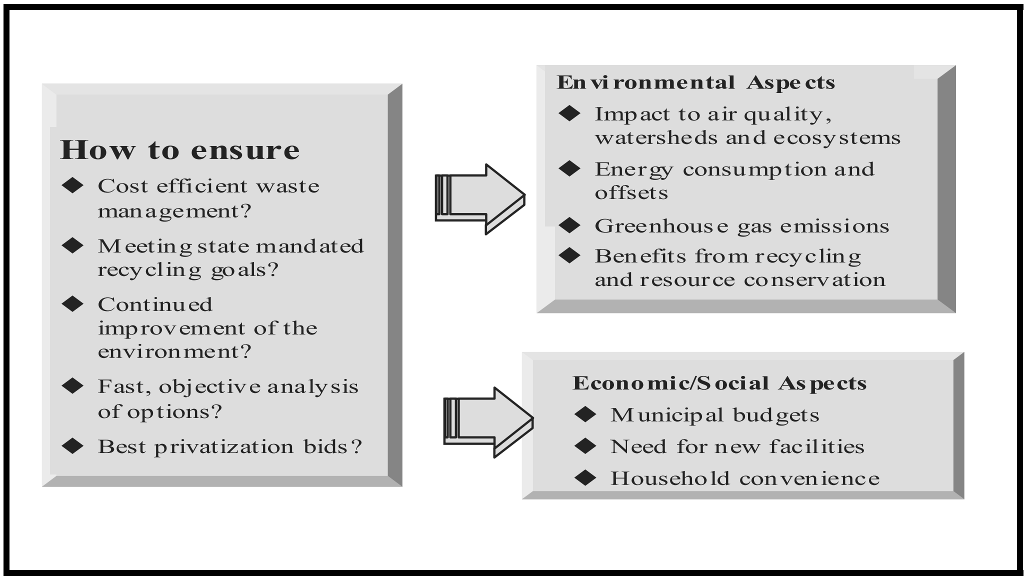


Figure 1. Types of Questions Addressed by the MSW Decision Support Tool

address. An internal review was carried out, including peer, quality assurance, and administrative reviews. In addition, three external peer reviews were conducted by experts in solid waste and life-cycle assessment (LCA). Additional input has been received through participation in the International Expert Group (IEG) on LCA for Integrated Waste Management. This provided a forum within the scientific community to discuss methodological issues, development of unit process models, and interpretation and presentation of results. (Coleman et al., 2003) The result of this effort is a tool that is credible, scientifically-sound, and tailored to the needs of U.S. decision makers

From all of this research, extensive data and information have been collected that provide the ability to quantify the life-cycle environmental tradeoffs and full costs for determining how best to manage waste. The database contains (1) environmental data for collection, transport, recycling, composting, combustion, and landfilling; (2) LCI data for the production and consumption of energy for the U.S. national and regional grids; and (3) LCI datasets for the production of aluminum, glass, paper, plastic, and steel. The database is a stand alone product available through RTI.

The MSW-DST has been used in over 30 applications to date. The tool can be used to optimize the selection of solid waste management options by cost per ton, energy consumption, particulate, nitrogen oxide, sulfur oxide, carbon monoxide, and greenhouse gas emissions. The systems to be evaluated may be existing, entirely new, or some combination of both, based on user-specified data. The MSW-DST is fully populated, requiring only basic data on waste quantity composition for the study. Defaults in the tool are based on either national or regional-specific averages, and all can be over-ridden using user-supplied information.

Results from the MSW-DST can be provided at increasing levels of detail and in graphical and numerical formats, depending upon the needs of the end user. (Solano et al., 2002a and b; Harrison et al., 2001; Barlaz et al., 1999b) For example, information can be presented as the total cost and LCI environmental burdens for a solid waste management option. It can also be evaluated for each individual process including collection, transportation, transfer station, material recovery facility, waste combustion, and landfill. This can be used to help determine what drives the cost and environmental burdens and to identify more efficient options.

The tool also incorporates a methodology for full-cost accounting (EPA, 1997). Full-cost accounting reflects the total costs rather than dollars per ton, which may not reflect actual costs such as long-term monitoring and maintenance of landfills. This information has been particularly helpful in reviewing bids and identifying those items that may drive overall costs. For example, changes to how the waste is collected such as the type of equipment, number of pick ups per week, and transportation fuel, can drive the economics as well as the environmental burdens. This can be evaluated easily using the MSW-DST, providing U.S. decision makers with access to information that will help them make more informed decisions by ensuring more effective and efficient environmental MSW management. (Thorneloe, et al., 1999)

Three examples of the use of this tool follow. These examples help to illustrate the variety of ways that the MSW-DST can be used to help identify more sustainable solutions to waste management. The paper concludes by answering the question about the connection between sustainability and waste management.

MSW-DST CASE STUDIES

Study of Management of Non-Recycled Organic Waste at EPA Research Facility

Construction of the EPA's facility in Research Triangle Park (RTP), North Carolina, was completed in 2002 using green building design. The EPA facility provides space to multi-disciplinary groups of environmental scientists and covers 11 hectares. This facility houses ~3,000 people, 400 individual laboratories, a conference center, a cafeteria, a national computer center, and a childcare center. Figure 2 provides a picture of the facility.

As part of the green building design at the RTP campus, responsible management of the facility's waste was a priority. In response, non-recycled biodegradable waste is being sent to a compost facility rather than a landfill. The MSW-DST was used to help quantify the associated environmental benefits.

Figure 2. New EPA Facility in Research Triangle Park, North Carolina

Three scenarios were constructed to compare the landfilling or composting the estimated 160 tonnes per year of non-recycled organic material that were being composted. This material included food waste, yard trimmings (grass, leaves, and branches), mixed paper, and animal bedding (wood shavings). Scenario 1 represents the waste being collected, compacted at a transfer station, and then hauled 145 km to a landfill. Scenario 2 represents the waste being collected and hauled 100 km to a compost facility. The compost facility is a windrow operation, and the compost is turned ten times during a 9-week composting and curing process. There is no pre-grinding or shredding of the food waste prior to composting. The final compost product is screened using a front-end loader and trammel screen. The third scenario is identical to the second, except that the compost facility is located within 2 km from EPA.

The next figures provide a comparison of the energy consumption, carbon equivalents (reported in million tones of carbon equivalent – MTCE), and nitrogen oxides for the three scenarios. The least energy efficient option is Scenario 2 (Figure 3), which also had the highest emissions of nitrogen oxides (Figure 5). The landfill option had the highest emissions of greenhouse gases (Figure 4) because of the inability to collect 100% of the landfill gas (that results from waste decomposition). The gas at the landfill is flared, although there is discussion underway about installing an energy recover project which would result in offsets and improve the environmental performance.

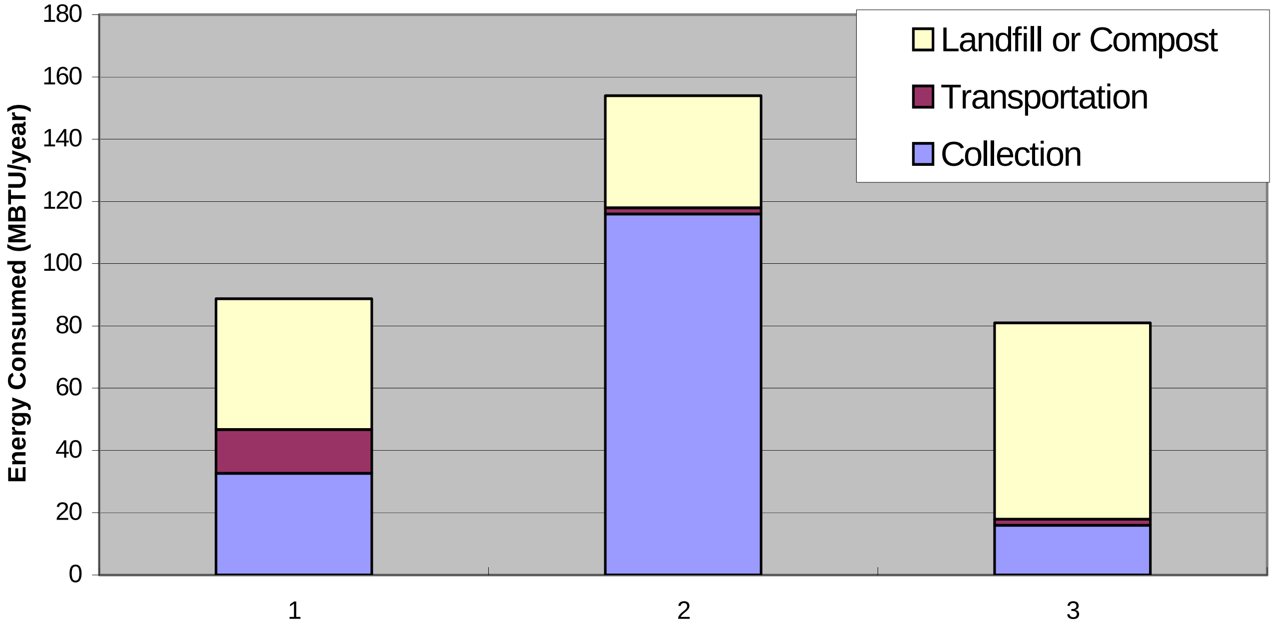


Figure 3. Annual Energy Consumption by Scenario

The major difference between Scenario 1 and 2 was in how the waste was collected and transported. The long-haul operation was more efficient and less polluting. The waste is collected using light-duty diesel trucks and transported to a transfer station. The waste is compacted and hauled to a landfill using a semi-tractor trailer. For Scenario 2, waste is collected using a light-duty diesel truck and hauled to the compost facility using the same collection truck. Scenario 3 was the most efficient because of the reduction in emissions from transportation. However, other factors must be considered, including economics, and facility design and operation.

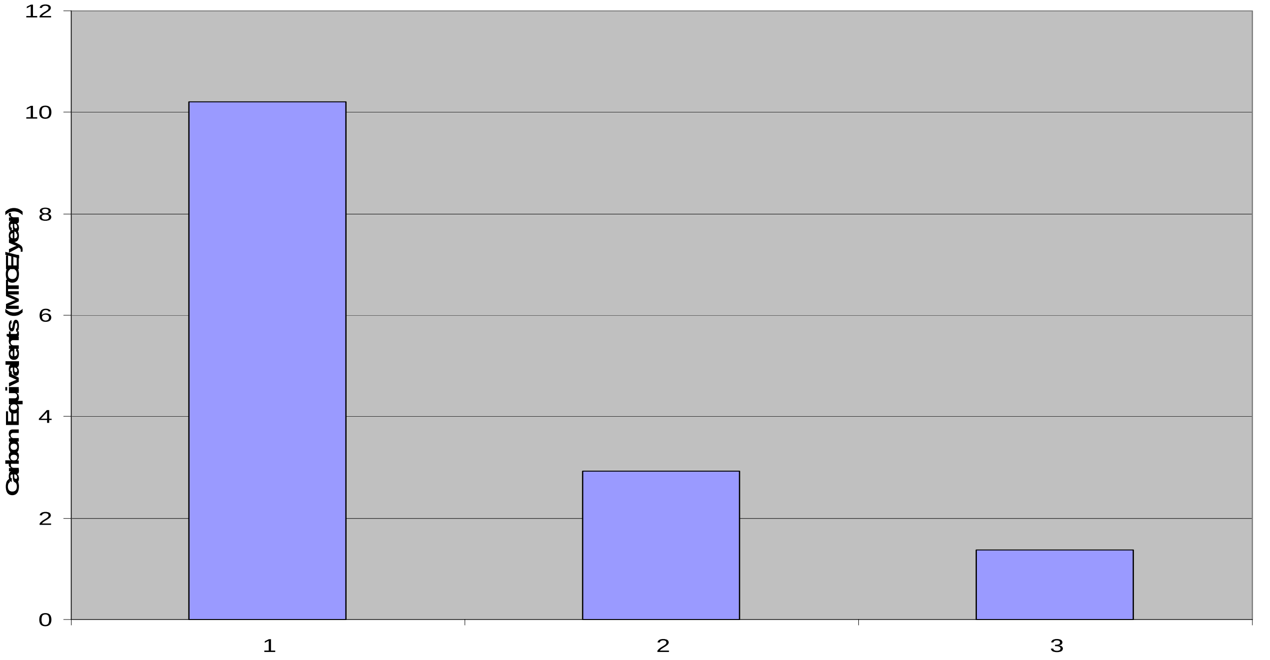


Figure 4. Annual Emissions of Greenhouse Gases by Scenario

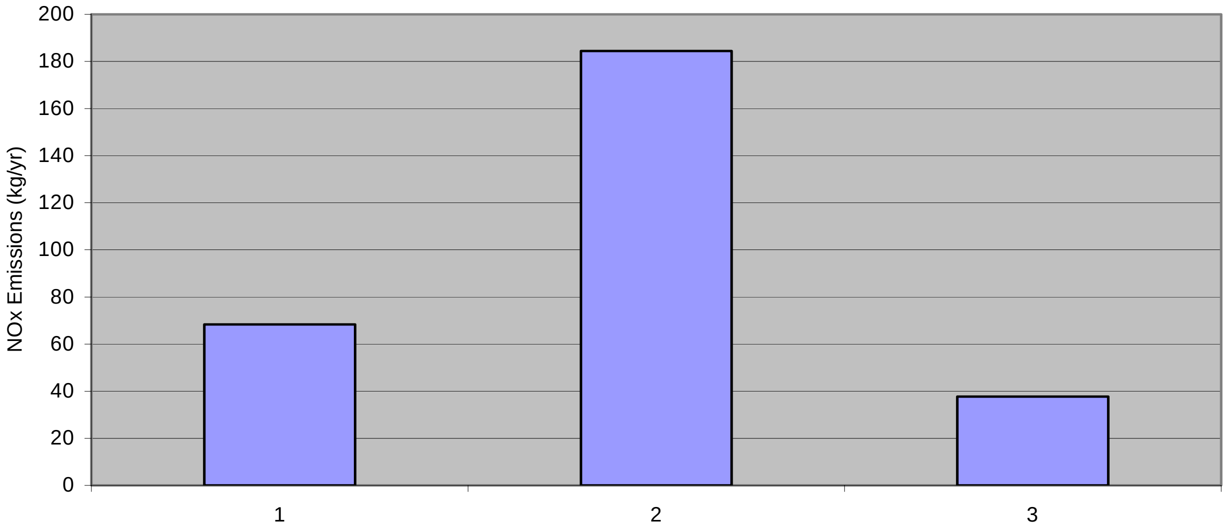


Figure 5. Annual NOx Emissions by Scenario

The Triangle J Council of Governments commissioned this study through funding from State of North Carolina. Their assumption was that the results would support their perception that composting is preferable to landfilling. However, because of the distance, type of truck, and inefficient collection operation, the MSW-DST results did not support this (Triangle J. Council of Governments, 2002). Since the report was released, options have been evaluated for locating a compost facility closer to EPA to result in improved environmental performance.

Conversion Technology Study for the State of California

New technologies for converting organic and plastic wastes to fuels and electricity, termed “conversion technologies”, are rapidly emerging. California State Assembly Bill 2770 (Chapter 740, Statutes of 2002) requires that the California Integrated Waste Management Board prepare a report on implementing these technologies for the non-recovered portion of the waste stream. The report is to include a description and evaluation of the life-cycle environmental and market impacts of the technologies as compared to existing MSW management practices. The technologies focused on in this study are non-combustion thermal conversion technologies, including acid hydrolysis, gasification, and catalytic cracking.

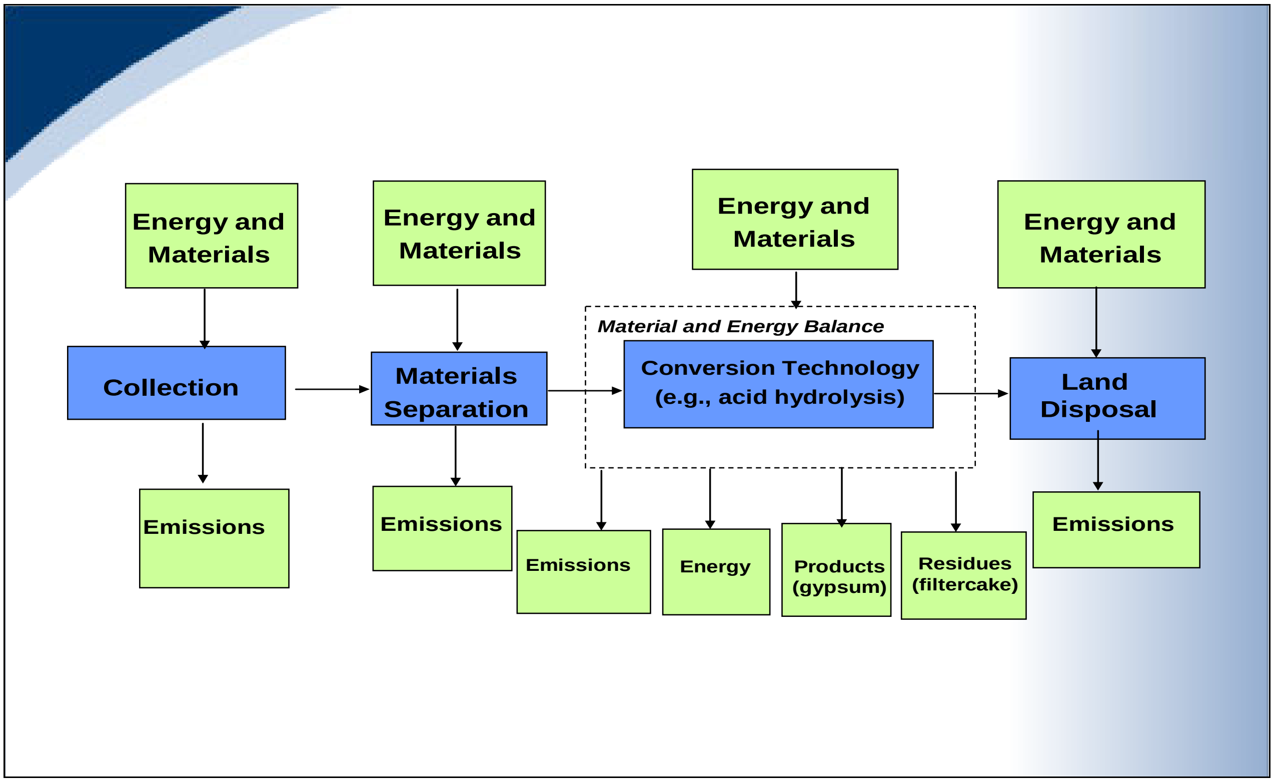


Figure 6. Life-Cycle Boundaries for Evaluation of Waste Conversion Technologies

To conduct the life cycle study, a hypothetical conversion technology growth scenario was developed for the Los Angeles and San Francisco regions for the years 2003 to 2010. Material and energy balances were constructed for each of the three conversion technologies and then expanded into a complete life cycle inventory for the hypothetical growth scenario (Figure 6). The inventory results from the growth scenario were compared against inventory results for existing waste management practices, including landfill disposal, recycling, composting, and waste-to-energy combustion.

Three different scenarios for landfills were included: venting, flaring, and recovery for energy use. For recycling, targets were evaluated including 35%, 55% and 75%. To help illustrate some of the findings, year 2010 results for the San Francisco Region are provided in Figures 7 and 8. The first figure presents a comparison of the net energy results in millions British Thermal Units (MBTUs). Figure 8 presents a comparison of the net carbon emissions. Waste combustion with energy recovery (waste-to-energy or WTE) was found to have significant energy benefits when compared to conventional technologies.

The results from this study suggest that the conversion technology scenario generally performed better than the existing waste management practices on a life cycle inventory basis. This outcome is directly related to the significant energy and emission savings from the implementation of these technologies. These savings result from fuel and energy production, as

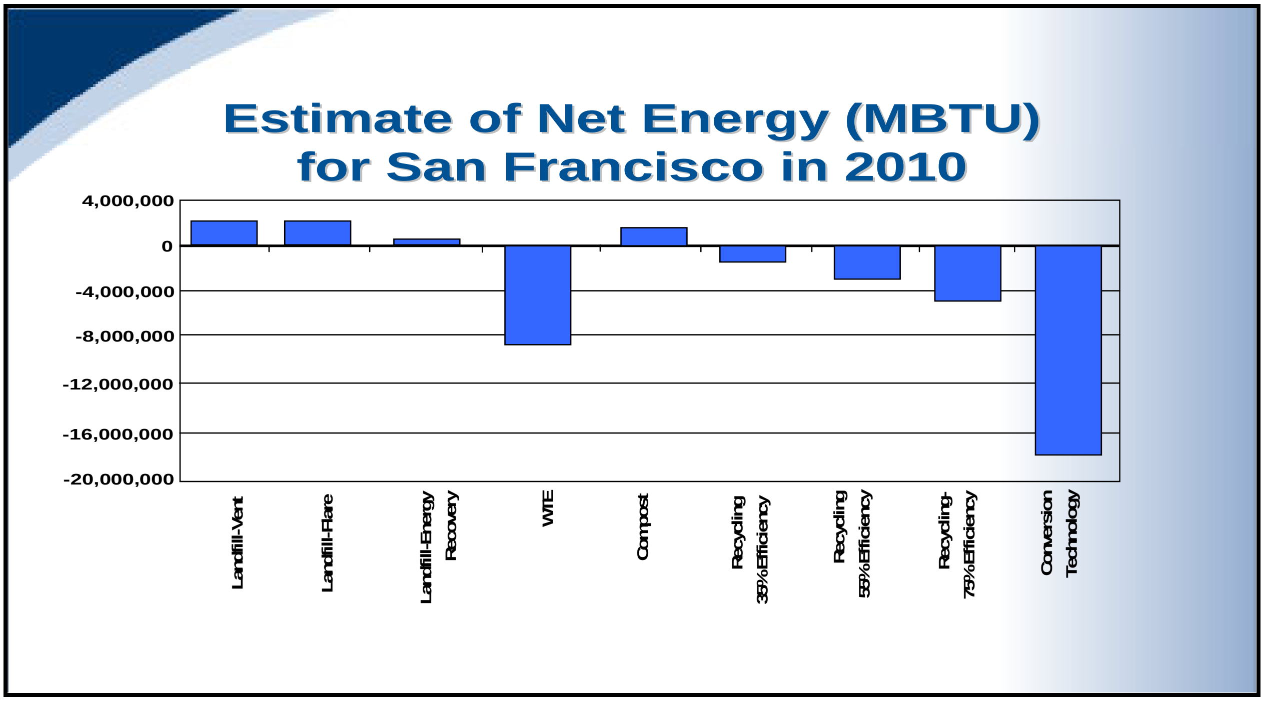


Figure 7. Evaluation of Waste Conversion Technologies – Estimate of Net Energy Results for San Francisco in 2010

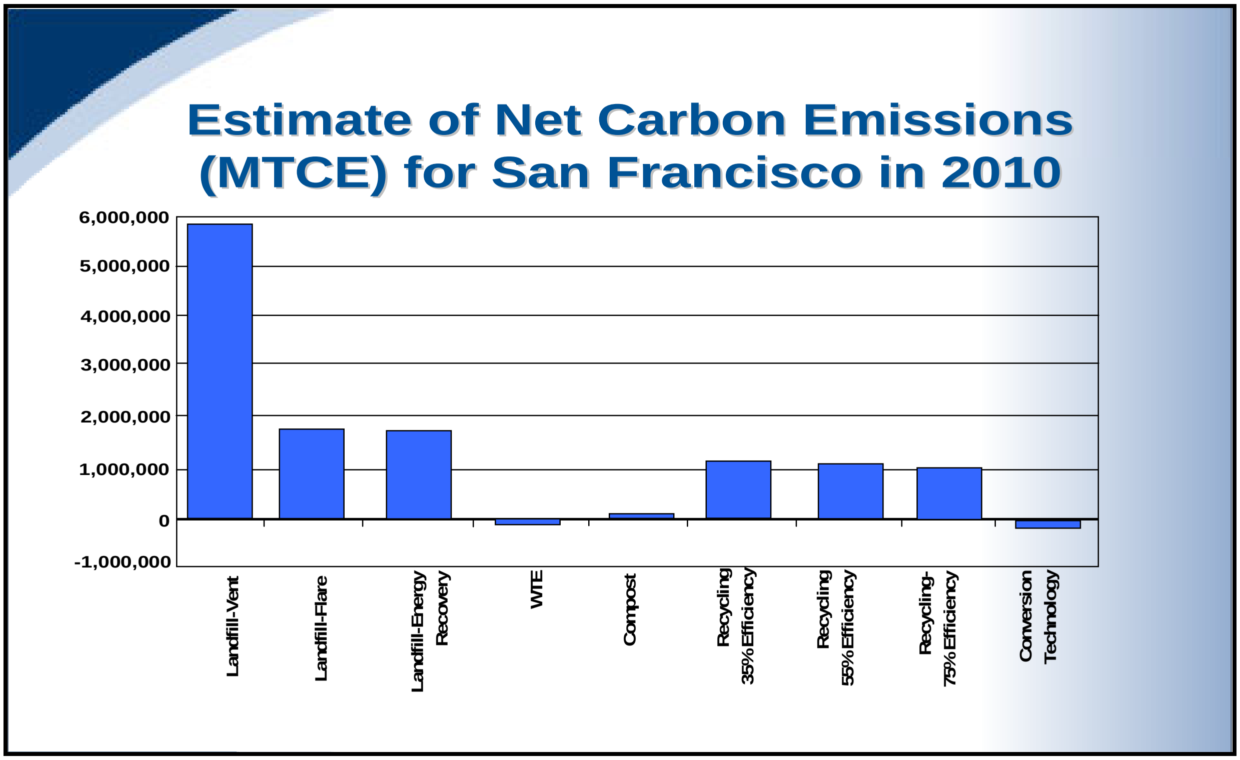


Figure 8 – Evaluation of Waste Conversion Technologies – Estimate of Net Carbon Emissions for San Francisco in 2010

well as additional materials recovery and recycling achieved through the up-front pre-processing systems required by the technologies. Since there are no operating facilities within the U.S. and very limited performance data, except for vendor-supplied information, there are a number of uncertainties in the results. This analysis is considered a first step in their evaluation to determine the suitability of conversion technologies in California. As pilot facilities are constructed, the analysis can be refined. There are also concerns about by-product emissions, which include dioxins, furans, and other hazardous air pollutants. The environmental benefits of the conversion technology are highly dependent upon their ability to achieve high conversion efficiencies and materials recycling rates.

Although this analysis is specific to the State of California, it is expected to be useful to other states and regions, both in content and by providing an example of a systematic, life cycle inventory approach toward waste management. This is the first time that such a holistic approach has been used to conduct an evaluation of conversion technologies by comparing them to conventional technologies in use today. A detailed report describing this study can be found on the web site of the California Integrated Waste Management Board (www.ciwmb.ca.gov).

Study Evaluating U.S. Greenhouse Gas Trends for Solid Waste Management

A study was conducted to present at the annual Fall Summit of the U. S. Conference of Mayor's Municipal Waste Management Association, held in Tacoma, Washington, on November 15 – 17,

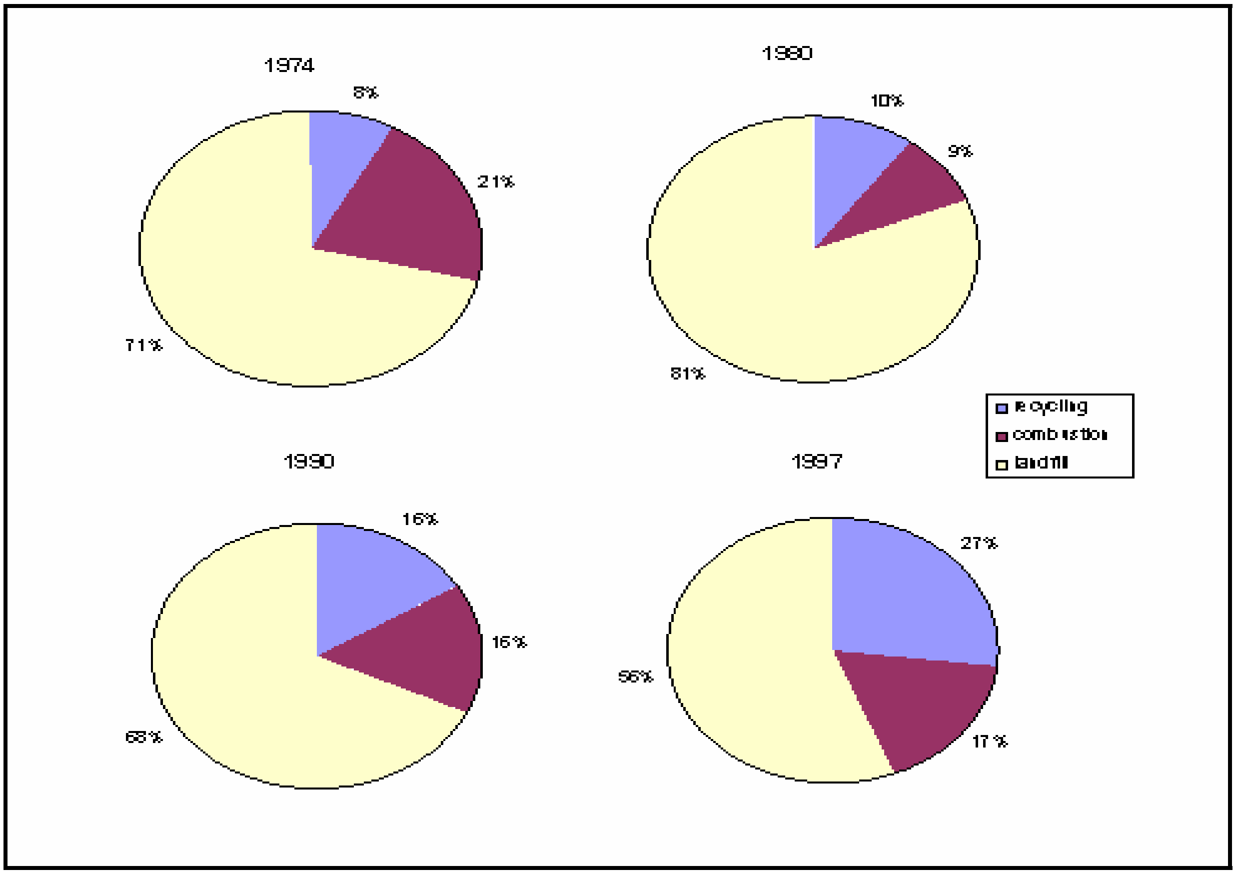


Figure 9. Changes in U.S. MSW Management from 1974 to 1997

2000. The study, which was published in the Air and Waste Management Association Journal (Weitz et al., 2002), included a detailed analysis of the waste composition, quantities, and management practices for the 1970s, 1980s, and 2000. The change in waste management practices for selected years is presented in Figure 9. The information was used to help determine the trend in greenhouse gas emissions over the past several decades. The mayors were interested in knowing whether resources that have been spent on improving solid waste management have resulted in environmental improvements. Figure 10 illustrates the technical approach that was used to account for the life-cycle environmental tradeoffs and the upstream and downstream impacts associated with resource conservation and recovery.

The results of the study indicated that a substantial reduction of greenhouse gas emissions from waste management has occurred since the 1970s. This is attributed to efficiencies in the move towards better integration of waste management programs, better control of landfills through gas control and energy recovery, energy and resource savings through recycling programs, and production of electricity from waste combustion facilities. A summary of these findings is presented in Figure 11. Actual greenhouse gas emissions are compared to the amount that would have been created if waste were still managed using 1970s technology. Although there has been

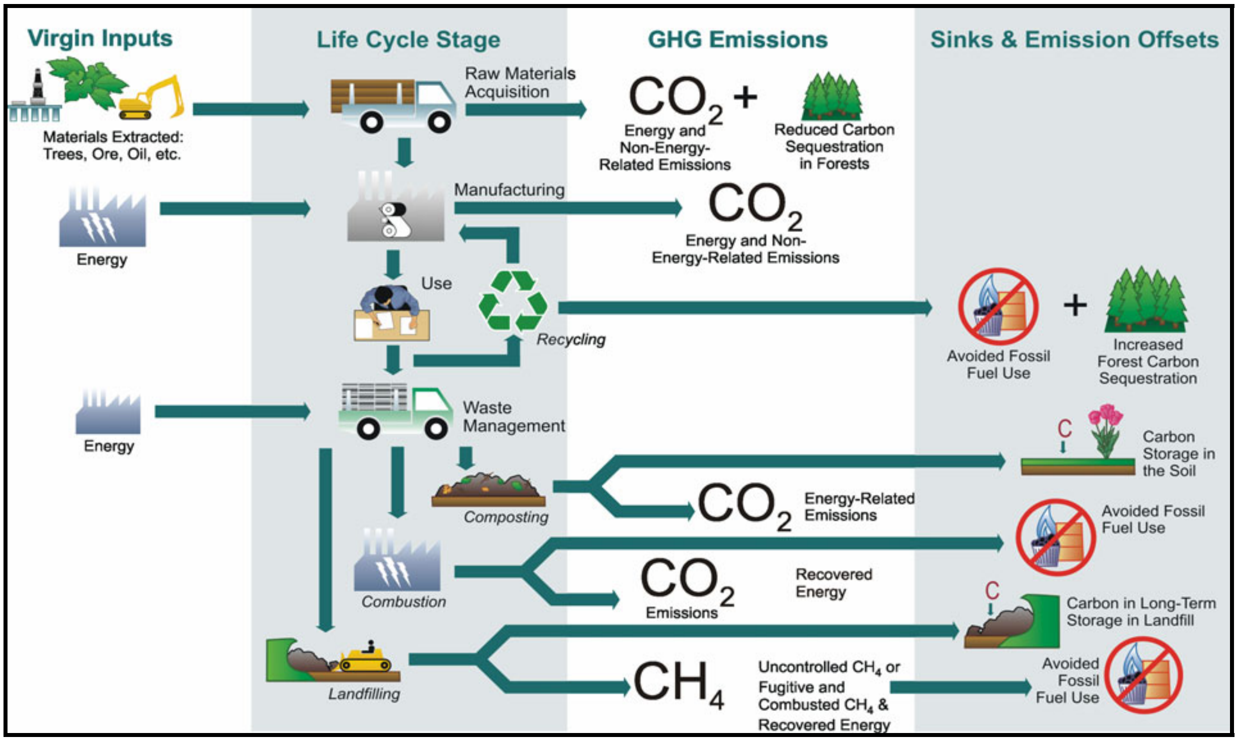


Figure 10. Material and Energy Life-Cycle Flows and the Associated GHG sources and Sinks

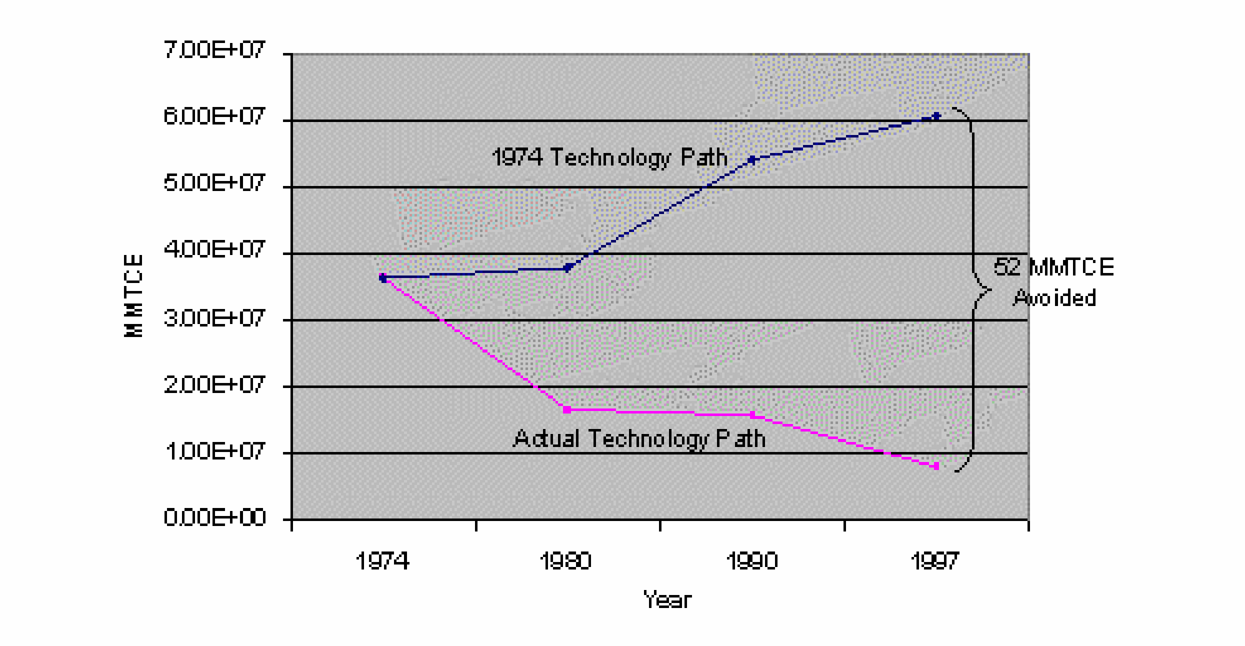
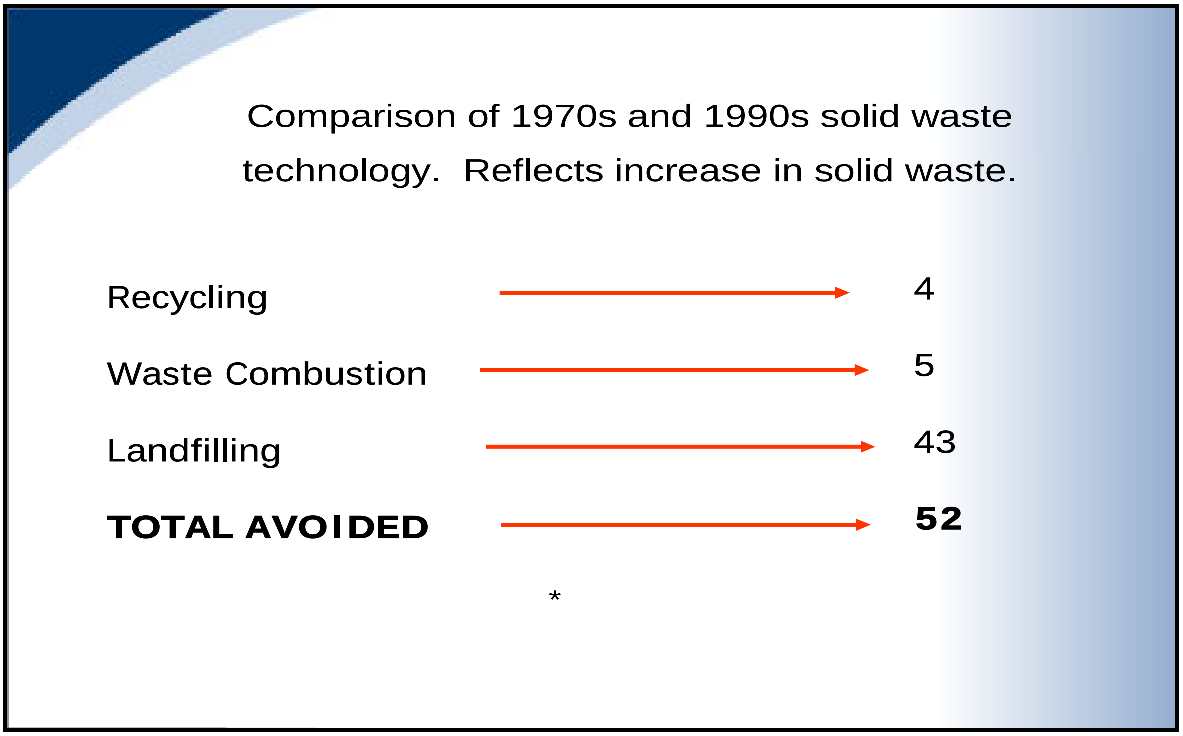


Figure 11. Net annual GHG emissions reductions for MSW management for actual technology in use compared to Net annual GHG emissions if 1970s technology were in use.



Comparison of 1970s and 1990s solid waste technology. Reflects increase in solid waste.

Recycling	4
Waste Combustion	5
Landfilling	43
TOTAL AVOIDED	**52**

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Figure 12. U.S. Greenhouse Gas Emissions Avoided in 2000 (MMTCE)

a 60% increase in the quantity of MSW since the 1970s, 52 million metric tons in 1997 of carbon equivalents (MMTCE) of GHG emissions per year are being avoided based on actions taken in the U.S. (Figure 11). The total quantity of GHG emissions was reduced by more than a factor of 6 (from 60 to 8 MMTCE) from what it otherwise would have been, despite the increased quantity of MSW. The information from this study has helped to better understand the contribution of greenhouse gases from waste management. The MSW-DST is being used on a community-level to help identify opportunities for further greenhouse gas reductions in addition to providing data on other environmental emissions.

THE RELATIONSHIP OF SOLID WASTE TO SUSTAINABILITY

Waste can have tremendous impacts on resource and energy use, greenhouse gas emissions, and pollution. Although the U.S. reached a recycling rate of 30% in 2000, a new goal of 35% has been set for 2005. Solid waste management is more integrated, efficient, and safer since the enactment of RCRA. Substantial environmental improvements have been made, but there is more that can be done. The RCC is providing the direction in the U.S. on how we can move from waste management to materials management.

The MSW-DST provides the ability to quantify the life-cycle environmental tradeoff and full costs in evaluating the management of materials collected from our waste stream. It provides the ability to optimize to identify more efficient and economical solutions for resource management. The MSW-DST is being used to help States, communities, industries, academia, and others in developing solid waste management plans. The MSW-DST helps support the goals of the RCC by helping to identify solutions that make better use of our resources. Hopefully, actions taken today will lead to more sustainable solutions and minimize the impacts to future generations resulting from solid waste management.

CONCLUSIONS

The U.S. EPA has initiated the RCC to help minimize waste and transition the U.S. towards materials management. The U.S. EPA, in partnership with RTI, has developed the MSW-DST which provides the means to quantify resource conservation and recovery. The MSW-DST has been used in over thirty studies to identify more efficient and effective solutions for waste and materials management. The majority of uses are for developing community-specific solid waste management plans. However, the tools can also be used for regional and national studies as illustrated by the second and third case studies.

Effort is underway to develop a web-accessible version of the tool. This will make for easier and cheaper access to the tool. Updates will be conducted as better data and information become available. We anticipate wider use of the MSW-DST once the web accessible version is available. This 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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