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WASTE-TO-ENERGY AND THE SOLID WASTE MANAGEMENT HIERARCHY

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1. INTRODUCTION

The SWANA Applied Research Foundation's (ARF) Waste-to-Energy (WTE) Group identified the issue of the waste-to-energy's ranking in the solid waste management hierarchy as one of high importance to the group.

Five organizations subscribed to the SWANA ARF's WTE group in FY2008 by making a funding commitment to the conduct of collective applied research in the WTE area. A listing of the current WTE Group subscribers is provided in Table 1.

Table 1 SWANA ARF FY2008 Waste-To-Energy Group

Jurisdiction/Company
HDR Engineering, Inc.
I-95 Landfill Owners Group
Lancaster County Solid Waste Authority
Southeastern Public Service Authority
Three Rivers Solid Waste Authority

This article presents highlights from a report that has been developed by the SWANA ARF staff to summarize the findings of recent research as well as currently available data and published information regarding the ranking of waste-to-energy in the solid waste management hierarchy.

2. THE EPA'S SOLID WASTE MANAGEMENT HIERARCHY

A hierarchy is defined in Webster's Dictionary as "a graded or ranked series."

Solid waste hierarchies, which rank available solid waste management approaches according to their environmental merits, have been adopted by the governments of the United States, Canada, individual U.S. states, and the European Union, as well as waste service companies, trade associations, and manufacturers.

In 1989, the United States Environmental Protection Agency (EPA) proposed a hierarchy of integrated waste management practices that quickly became the basis for state recycling laws. This hierarchy graded technologies based on an existing hazardous waste model that placed waste prevention over reuse, and reuse over disposal or incineration. When applied to municipal solid waste, however, reuse took on the strict definition of recycling and composting. Other technologies capable of meeting the policy objectives associated with landfill diversion – such as waste-to-energy – were either arbitrarily placed lower in the hierarchy or left out altogether.[1]

The EPA's Municipal Solid Waste web site includes a page entitled "Frequently Asked Questions about Recycling and Waste Management", where it describes the U.S. solid waste hierarchy (see Figure 1). According to the web site,

> "The four-tiered solid waste management hierarchy (shown in the pyramid below) ranks the most preferable ways to address solid waste. Source reduction or waste prevention, which includes reuse, is considered the best approach (tier 1) followed by recycling, which includes composting (tier 2). Waste that cannot be prevented or recycled can be

[1] Martin, K. "A Brighter Shade of Green," *MSW Management*, Feature Article, March/April 2001.

combusted with energy recovery (tier 3). Tier 4 is landfilling or incineration without energy recovery."

From this description, it can be seen that waste-to-energy is ranked lower than recycling and composting by the EPA.

Also, the EPA is inconsistent with respect to the ranking it gives waste-to-energy. On the "Basic Facts" page of its web site, it is stated that "EPA has ranked the most environmentally-sound strategies for MSW" and that

> "Source reduction (including reuse) is the most preferred method, followed by recycling and composting, and, lastly, disposal in combustion facilities and landfills."

In this description, the EPA implies that the environmental impacts of waste-to-energy are equal to those associated with landfill disposal of waste.

Fig. 1 U.S. EPA Solid Waste Management Hierarchy

The purpose of the EPA's solid waste management hierarchy is to provide solid waste policymakers, planners, managers, and the general public with a relative ranking of the most environmentally-preferable ways to manage solid waste. However, the hierarchy has been criticized by a number of the organizations involved in the planning and implementation of solid waste management systems for the following reasons. As concluded in a recent paper,

> "There is an increasing awareness that the waste management 'hierarchy,' which ranks treatment options in a descending order of desirability, is of very limited use. There is no scientific basis for ordering waste management treatment options in this way. The hierarchy cannot provide any guidance with respect to using combinations of treatment technologies… In addition, the waste management hierarchy does not, and cannot, address cost issues and will not identify the best practical environmental option with respect to planning waste management systems."[2]

3. THE EPA'S MUNICIPAL SOLID WASTE – DECISION SUPPORT TOOL

The evaluation of the environmental impacts of a product over its life cycle – from the extraction of the raw materials used for its production to its ultimate disposal – is referred to as an "environmental life-cycle assessment," or LCA."

In the field of solid waste management, it has long been recognized that the recycling and recovery of materials and energy from discarded products or materials can result in a significant reduction in the net environmental impact of that product. For example, the recycling of aluminum cans reduces the need for the mining and processing of bauxite while the incineration of paper and plastics reduces the need for the mining and combustion of fossil fuels such as coal.

The conduct of life cycle assessments enables solid waste managers and policymakers to quantify and evaluate both the direct and indirect environmental impacts associated with local solid waste management alternatives.

In recent years, a number of computer models have been developed that can be used to conduct life-cycle assessments of solid waste management options. An excellent review of these models is presented in a paper published in 2000 in Waste Management Research and are summarized below:[3]

- The EPA's Office of Research and Development (EPA ORD) has developed a "Municipal Solid Waste Decision Support Tool," or MSW-DST, for local government solid waste managers to use for the life-cycle evaluation of integrated solid waste management options. The MSW-DST was with the assistance of numerous outside contractors and organizations, including the Research Triangle Institute, North Carolina State University, the University of Wisconsin-Madison, the Environmental Research and Education Foundation, Franklin Associates, and Roy F. Weston, Inc.

- An important facet of the model development strategy was the creation and consultation of a number of internal advisors and over 80 external "stakeholders" regarding the approaches, assumptions, and data inputs used by the MSW-DST to quantify environmental impacts. The high level of involvement of these stakeholders – along with the conduct of three

[2] McDougall, F.R., and Hruska, J.P. 'Report: the use of Life Cycle Inventory tools to support an integrated approach to solid waste management," *Waste Management Res 2000*: 18: 590-594.
[3] Ibid.

external peer reviews – helped ensure the objectivity of the DST and the credibility of its results.

- The MSW-DST has been used to evaluate solid waste management alternatives in over 50 federal, state, and local government applications. Many of these evaluations involved the quantitative analysis and comparison of the environmental impacts of waste-to-energy to other solid waste management options, including recycling, composting, and landfill disposal.

4. THE EPA'S ASSESSMENT OF THE LIFE-CYCLE ENVIRONMENTAL IMPACTS OF SOLID WASTE MANAGEMENT SYSTEMS

Recently, the MSW-DST was used by the EPA to identify solid waste management strategies that would help to meet the goal of the EPA's "Resource Conservation Challenge." [4]

In this effort, ten solid waste management strategies were evaluated for a hypothetical, medium-sized United States community with a population of 750,000 and a waste generation rate of approximately 3.5 pounds per person per day (Table 2). The assumed waste composition was based on national averages.

Based on the outputs of the MSW-DST model, the EPA reported the following findings:

- **Climate Change** – "The most attractive strategy from a greenhouse gas perspective is the Scenario 8" (i.e., the WTE Scenario).

- **Acidification** – "The WTE scenario (scenario 8) shows the greatest offset of acidification-related pollutants primarily because it results in the largest energy offset."

Table 2 Waste Management Scenarios Evaluated by the EPA

Scenario	Description
1	10% recycling, 90% landfilled with no gas collection and control.
2	20% recycling, 80% landfilled with no gas collection and control.
3	30% recycling, 70% landfilled with no gas collection and control.
4	40% recycling, 60% landfilled with no gas collection and control.
5	30% recycling, 70% landfilled; landfill gas is collected and combusted using flares.
6	30% recycling, 70% landfilled; landfill gas is combusted using internal combustion engines to produce electricity.
7	30% recycling, 70% landfilled; landfill gas is piped to nearby industrial facility and combusted in boiler (displacing fuel oil).
8	30% recycling, 70% combusted using WTE facility (generating electricity versus coal-generated electricity and recovering metals from WTE ash).
9	Same as Scenario 5 except waste is collected and transported to transfer station and then long-hauled 800 kilometers (500 miles) to landfill using semi-tractor trailer transfer vehicles.
10	Same as Scenario 9 except waste is long-hauled to landfill by rail.

[4] Thornloe, S., Weitz, K. and Jambeck, J. "Application of the U.S. Decision Support Tool for Materials and Waste Management." *Waste Management Journal- Special Edition* (May 2007). The EPA launched the Resource Conservation Challenge in 2002 to help reduce waste and move towards more sustainable resource consumption.

- **Smog** – "The WTE scenario (scenario 8) shows the greatest offset of smog-related pollutants because it offsets the most electrical energy."

- **Human Health Effects – Cancer Related** – "(There is) relatively little difference between the scenarios for cancer-related health effects except for scenario 10, which transports waste using long-haul by rail."

- **Human Health Effects – Non-Cancer Related** – "…the results are negative for all scenarios" (i.e., all scenarios provide non-cancer related human-health benefits since they reduce non-cancer related pollutants)."

In summary, the WTE scenario was found to provide significantly higher environmental benefits with respect to climate change, acidification, and smog. It was also found to equal or better than other scenarios with respect to reducing human-health effects (both cancer and non-cancer related). The benefits of the waste-to-energy scenario were graphically illustrated in the EPA study and these graphs are reproduced in Figures 2 through 5.

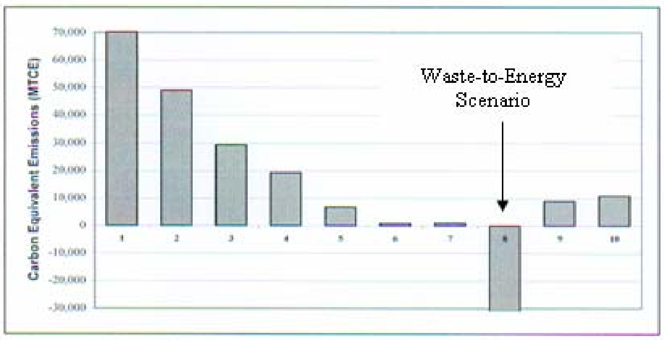

Fig. 2 Waste-to-Energy Scenario – Climate Change Benefits

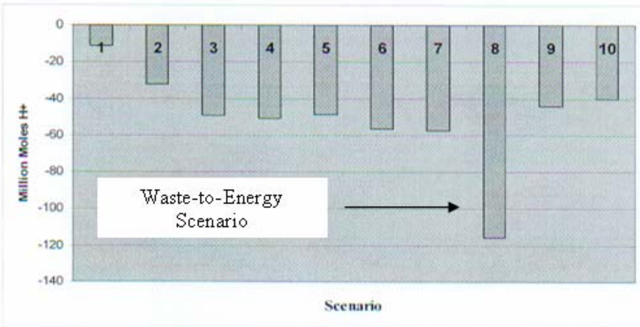

Fig. 3 Waste-to-Energy Scenario – Acidification Benefits

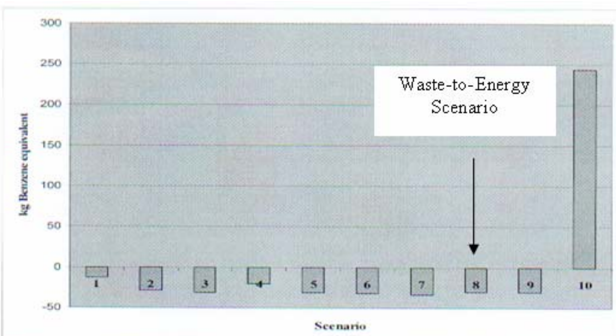

Fig. 4 Waste-to-Energy Scenario – Human Health Cancer Risk Benefits

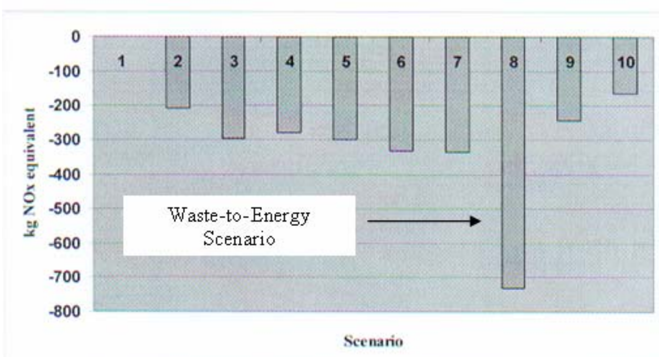

Fig. 5 Waste-to-Energy Scenario – Smog Reduction Benefits

5. CLASSIFYING AND RANKING U.S. SOLID WASTE MANAGEMENT SYSTEMS

Three generic types of solid waste management system options that represent the vast majority of systems in the United States can be culled from the ten alternatives evaluated by the EPA. These three systems are presented in Table 3 and summarized below:

- **Recovery-Based System** – This system is referred to as a "recovery-based system" since a majority of the community's waste (80%) is recovered for materials recycling and electricity generation. In this system (identical to Scenario 8), 30% of the community's waste is recovered through recycling through source separation and collection; 50% is recovered at a waste-to-energy facility that generates electricity and recovers metals; and 20% of the waste is landfilled in the form of inert ash. In a recovery-based system:

  - Recyclables are source-separated by single-family and multi-family residents for collection on a weekly basis and subsequent processing at a materials recovery facility. Commercial recyclables are also source-separated and recycled.
  - Yard waste is also collected from residences at the curb and processed at a yard-waste composting facility.
  - Mixed waste is collected at the curb on a weekly basis and is processed in a "mass-burn" waste-to-energy facility, which generates electricity, thereby, displacing coal. Metals are recovered from the ash with the remainder of the ash being disposed in a landfill.

TABLE 3
U.S. SOLID WASTE MANAGEMENT SYSTEMS - PERCENTAGES OF WASTE STREAM RECOVERED OR MANAGED BY EACH PROCESS

System Type	Percentage of Solid Waste Stream Recovered or Managed		
	Recycling[1]	Waste-To-Energy	Disposal[2]
Recovery-Based System	30%	50%	20%
Disposal-Based System: Local Landfill	30%		70%
Disposal-Based System: Regional Landfill	30%		70%

[1]Assumes curbside recycling and yard waste composting.

[2]Nationally, 30 million tons of MSW are combusted in WTE facilities and 3 million tons of WTE ash are reused annually, which equates to 1/3 of all residue. Source: Integrated Waste Services Association.

- **Disposal-Based System – Local Landfill** – This system is referred to a "disposal-based system" since a majority of the community's waste (70%) is ultimately landfilled. In this type of system (identical to Scenario 6):

  - Recyclables are source-separated by single-family and multi-family residents for collection on a weekly basis and subsequent processing at a materials recovery facility.

Commercial recyclables are also source-separated and recycled.

- Yard waste is also collected from residences at the curb and processed at a yard waste composting facility.

- Mixed waste is collected at the curb on a weekly basis and is disposed in a "Subtitle D" landfill located in close proximity to the community generating the municipal solid waste. The landfill gas is collected and combusted in internal combustion engines to produce electricity for sale to the local electric utility.

- **Disposal-Based System – Remote Landfill** – This system is identical to the disposal-based system described above except that the landfill is located in another community at a significant distance from the community, which generates the waste.[5] In the EPA study, the mixed waste is assumed to be transported to the remote landfill in large transfer trailer trucks. This system is identical to Scenario 9 except that landfill gas is recovered to generate electricity instead of being flared. In this regard, the environmental benefits of this system option will be somewhat higher than those presented for Scenario 9.

6. CONCLUSIONS AND RECOMMENDATIONS

The current hierarchy established by the EPA for municipal solid waste management focuses on solid waste process options and, therefore, has limited value with respect to the implementation of solid waste management systems in local communities. For this reason, it is recommended that the EPA establish and promote an additional hierarchy based on the net environmental benefits of the generic types of solid waste systems that have been commercially proven and are available to local communities to manage solid waste. The hierarchy for solid waste system alternatives suggested by EPA's research is presented in Figure 6.

In addition to the environmental benefits quantified by the EPA through the MSW-DST model, other benefits of recovery-based systems that should be highlighted include waste stabilization, avoidance of accidental risks associated with long-haul truck transport, conservation of fossil fuels, long-term control over processing capacity and costs, and the recovery and recycling of metals not targeted for collection in curbside recycling programs.

[5] In the EPA study, a one-way distance to the remote landfill of 500 miles is assumed.

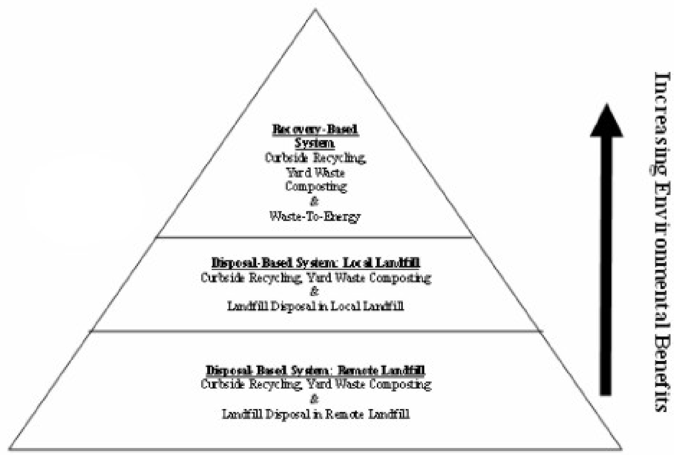

Fig. 6 Solid Waste Management Systems Hierarchy Suggested By EPA Research