Chapter 2

The MSW System in Transition

CONTENTS

Boxes

Figures

Tables

Chapter 2

The MSW System in Transition

INTRODUCTION

The United States is a land of abundant natural resources. Although the limitations of this great wealth are becoming apparent-declining energy resources, polluted air and water, rising land costs, signs of industrial decline—societal attitudes regarding the use of this wealth have not yet adjusted. Our social and economic philosophies in many ways still emphasize ‘‘consumerism, ’ tending to divert attention away from the idea of resource conservation. We have a high per-capita waste generation rate, and that rate seems to be increasing (ch. 3).

There is no easy answer to the question of why our society has become such a prodigious waste producer, nor is there an easy way to reverse this trend. Some elements that contribute to the overall trend are obvious: for instance, factors such as a product’s appearance and convenience are more important to today’s consumers than where it came from and what will happen when it is discarded. Other elements are less visible, however. As our standard of living has increased and a smaller share of the population is engaged in the physical production of goods, people have become less aware of how materials are obtained and transformed into usable products.

Whether the tendency toward increased waste is an inherent characteristic of U.S. consumers or whether it is the result of manufacturers’ advertising is unclear. It is true, however, that in the past product designers and manufacturers have not been burdened with the responsibility for the ultimate fate of their products, that is, what happens to the products after they are used. Neither have the majority of consumers been concerned with the ultimate disposal of their waste.

Heightened concerns about our industrial prowess, our deteriorating environment, and what some claim to be an apparent lack of concern for the future are forcing us to reexamine our values. The problems emerging with MSW reflect this convergence of concerns: can U.S. industry respond adequately to help us generate less MSW; can we devise better materials use and waste management strategies; and are we willing to work today to ensure that future generations are not forced to pay a high price for our carelessness?

This chapter briefly examines societal, institutional, and industrial influences that have shaped the present MSW situation. Understanding the evolution of the problem and the dynamics of the “system” that manages our MSW can help illuminate likely targets for change. The chapter begins with a discussion of the interrelationships among production decisions, consumption patterns, waste generation, and MSW management. The evolution of the public and private waste management infrastructure also is described. Two key issues affecting the entire MSW system—the risks and the costs associated with different management methods—are also examined.

MSW GENERATION AND MANAGEMENT AS PART OF A “SYSTEM”

The nature and quantity of MS W that we generate, and how we manage it, are determined by a multitude of decisions made at all levels of the socioeconomic system. Linkages among different stages in the lifecycle of MSW—product design, manufacture, distribution, use, and discard-often are unclear and may even be invisible. Each of these linkages represents a leverage point for changing decisions and thus the MSW status quo. But people’s awareness of the MSW system, and their role in it, is growing, especially in parts of the country where waste disposal costs have increased and disposal capacity has declined. For example, the intense public opposition to the siting of MSW management facilities has prompted some citizens to question their own consumption patterns and waste disposal practices.

Product Design and Manufacture: The Beginning of the MSW Lifecycle

The design of products has enormous influence on MSW management. For example, products that contain potentially toxic substances, for whatever functional reasons, have led to concerns about human health and environmental risks associated with landfilling, incineration, and recycling (see "Risks Associated With Management Methods" below).

Product design is very dynamic. Manufacturers continually change products for reasons that include increased marketability and safety and decreased costs of production and materials. This has led to many changes that ultimately effect MSW management-e.g., the shift in packaging and containers to using lighter materials such as plastics and paper in place of glass and metal (chs. 3 and 4).

In general, however, the entire production end of the MSW lifecycle has not received much attention as a focus for solving MSW problems, at least until recently. Design and production changes are rarely undertaken in response to concerns about MSW management. Although manufacturers have incentives to reduce the costs and liabilities associated with their industrial wastes, they have little incentive to worry about disposal costs for their final products (ch. 1). This, in turn, means that changes in product design can have unintentional, negative effects on MSW management-e. g., the use of multi-material packaging can make such packaging more difficult to recycle.

Now, however, there is growing awareness of the link between the design and production of consumer products and MSW management problems. In a few instances, issues related to MSW management have manifested themselves at the product design stage (e.g., degradable plastic bags, mercury-free household batteries). There is a growing movement advocating "design for recycling,' i.e., designing products to be recyclable or to use more recycled materials. This concept could be extended to include ''design for reduction,' a call for products designed to be less toxic or more durable, or to use fewer materials. These changes all could have positive effects on MSW management (chs. 1 and 4).

The Federal Government, State governments, industries, and consumer groups are all wrestling with how to promote these types of changes. State governments in the Northeast, for example, have created a waste reduction task force to work with industry on ways to reduce MSW toxicity and quantity (ch. 8). Working with the Conservation Foundation, EPA sponsored a dialog beginning in 1988 on MSW reduction, with representatives from government, industry, academia, and public interest groups (ch. 8). Continued and increased interest in how to address product design will be a critical factor in the future success of MSW reduction and recycling efforts. OTA discusses policy options related to these issues in chapter 1.

Changes in the Public and Private Waste Management Infrastructure

The Evolution of Waste Management Practices

In the past, waste management meant simply getting rid of the trash. Often, this was done for a low cost by a local, privately owned waste disposal company, the municipality, or sometimes by residents at a local dump. Government attention to waste was minimal, even at the local level. Municipal government involvement in waste management consisted, at the most, of owning collection vehicles and the landfill. No consideration was given to how much waste was generated or to its characteristics. No one really cared what ended up at the landfill or where it came from. '

Most recovery of materials for recycling occurred at no cost to residents because it was done by local private scrap collectors or by volunteer groups as a fund-raising activity. The volume of materials collected was dependent on the price for the materials in the marketplace. When prices fell, collection declined and when prices increased, collection increased. Waste collection and disposal costs were generally not affected, however,

Some additional materials recovery occurred outside the purview of the municipal budget at drop-off or buy-back centers operated by charity

---

[1] Experiences of local governments with MSW management, including the myriad of problems that have faced local officials. are discussed in ch. 8.

groups or environmental organizations.[2] These centers became particularly popular during the 1970s, when social awareness of resource conservation and environmental protection was high. However, neither these centers nor the traditional scrap industry were viewed as part of the waste management system.

At the same time, litter reduction efforts also increased, and several States passed beverage container deposit legislation (ch. 8). The costs of these programs were borne principally by the beverage industry, the consumer, and the retail sector. Studies indicate that this type of legislation reduced beverage container litter by as much as 80 percent (9,12). In general, however, the legislation was not oriented toward waste management, and the reduction in the amount of MSW sent to incinerators or landfills was less than 5 percent.[3]

By the mid-1970s, the recovery of materials and energy from MSW as a waste management alternative was entering its infancy, especially in terms of government policy. Technologies for recovering energy and materials from mixed waste were unproven, and many municipalities were wary of the financial, social, and political risks involved. Many private firms, however, viewed energy and materials recovery as promising business opportunities and rushed to offer related products and services. Firms expanding into these activities included those involved in pollution control, petrochemicals and oil, aerospace, solid waste collection and disposal, containers and packaging, engineering and construction consulting, and machinery and equipment manufacturers (2). In other words, there was no shortage of willing entrants into the emerging, but yet unknown, materials and energy recovery segments of the waste management field.

Since that time, energy recovery and, more recently, materials recovery have proven to be a boon to the waste management business. Numerous technologies have been developed to recover materials from mixed MSW, to sort commingled recyclable, or to process recyclable separated by waste generators (i.e., by households, offices, etc.). Although these types of activities were once viewed as being oriented toward commodities—designed to profit strictly from the marketing of materials-they are now also viewed as a waste management service. In some instances, municipally owned materials recovery facilities compete with private recyclers, further spurring the private sector to view recovery of materials from waste as a business opportunity.

Photo credit: *Office* of Technology Assessment

Consumers can often take separated materials such as used aluminum beverage cans to a "buy-back" center that pays for the materials and then further processes them for market.

Many of these changes in the structure of the waste management industry occurred over several generations. Box 2-A describes these types of changes for one California community.

The Current Status of the Waste Management Industry

By 1988, analysts were projecting waste management industry-wide revenues of$18 billion over the years 1988 through 1995 from waste-to-energy incinerators alone (19). The materials recovery

---

[2] A drop-off center can be a permanent site or a mobile trailer accepting one or more materials. These centers are often operated by nonprofit groups or by communities. A buy-back center has a similar arrangement, except that cash is exchanged for the material. Aluminum recycling centers, often operated by aluminum companies, are the most prevalent form of buy-back operation.

[3] Metal, glass, and plastic beverage containers covered under these programs normally make up about 5 percent of the waste stream.

Box 2-A-Generations of MSW and Materials Management

Adaptation and innovation—in collection, management methods, and financing-have proven to be key ingredients in the evolution of MSW management in Marin County, California. One of the driving forces behind the county's ambitious recycling program is Joseph J. Garbarino. For Garbarino, MSW management is more than a business, it's a family tradition. Marin Sanitary Service, a waste collection and hauling company that is over 40 years old, is owned by Garbarino and three partners. Garbarino's father, John, an Italian immigrant, was a garbageman and his daughters, Susan and Patricia, work in the business. Garbarino notes that many people in the Bay area garbage business had uncles, fathers, and grandfathers who hauled garbage there earlier in the century.

The latest advance in the business is a recycling processing facility, the Marin Resource Recovery Center in San Rafael, that is generations removed from earlier methods of collection and management. Earlier in the century, scavenging (an 'old name for recycling,' according to Garbarino) was a normal part of garbage collection and scrap dealers played an integral role in managing discarded materials; in the early 1920s, garbagemen in the Bay area even formed the Scavengers' Protection Association to avoid competing too strenuously among themselves. A team of men would set out collecting burlap garbage sacks, with one man sorting the discards on a horse-pulled wagon or later on a flatbed truck. Anything that could not be reused was disposed of in San Francisco Bay, apparently helping to build Treasure Island. As the consequences of this disposal method became better understood, techniques began to change. ' 'Sanitary landfills' became the favored MSW management tool; the San Quentin Disposal Site operated from 1958 to 1987$ and Marin Sanitary Service began disposing MSW in the Redwood Landfill in 1948.

At about this same time, compaction collection trucks were introduced in Marin County. The advent of these "packer" trucks in the late 1950s was a significant reason that many garbage collectors stopped recovering materials for several decades. In the late 1970s, after some of the initial recycling enthusiasm of the early 1970s (which had spawned and seen the demise of numerous community recycling programs) had settled, Marin Sanitary Service became re-involved in the business of recycling. Garbarino helped develop Marin Recycling, a pioneering residential curbside collection program owned by three companies, with initial funding from the California Waste Management Board. In 1980, Marin Recycling bought its first recycling collection trucks. Given recent trends, Garbarino predicts that one day the county will have more recycling collection trucks than packer trucks.

For Garbarino, the orientation toward recycling is practical and wise business. He argued early for curbside collection of recyclable because it would prolong the life of local landfills and give area trash haulers additional business opportunities. Today, Garbarino stresses the importance of managing waste in ways that are environmentally sound as well as profitable, and he supports increased waste reduction and recycling efforts.

Since 1980, the curbside program has collected cans, bottles, and paper-initially about 1,000 tons per *year,* currently **22,500** tons per year. The facility also accepts a similar amount of source-separated materials from nearby cities. An innovative recycling surcharge conceived by Garbarino was adopted by the 16 participating communities to subsidize the program. It helped the program survive a recession shortly after it began and the surcharge is still in place today, 8 years later. Marin Recycling now services about 168,000 of the 225,000 residents in the county. In 1987, Marin Sanitary Service opened the Marin Resource Recovery Center, housed on an 18-acre site in San Rafael, to process recyclable. The center receives about 5,000 to 6,000 tons of materials a month, mostly from the commercial sector, and recovers about 1,500 tons a month (other residues and trash loads are sent to a landfill). The $9.5 million center was financed for Marin Sanitary Service by a local bank. It receives materials from private haulers who are charged a tipping fee and from the commercial collection program. The center also buys baled cardboard from grocers and re-bales it for export. In addition, a collection of pigs, rabbits and other farm animals consume some of the food waste from local restaurants and grocers.

Garbarino plans to expand the apartment complex component of the residential curbside program and may build a refuse-derived fuel facility in an effort to meet Marin County's 50 percent recycling goal. Today, Marin Recycling and the Resource Recovery Center collect and divert between 20 to 30 percent of source-separated materials from residences and businesses for recycling. Over the years, Garbarino has worked closely with the communities and their local and State public officials. Undoubtedly, this cooperation will be important to the future evolution of Marin County's MSW and materials management approach.

SOURCE: J.J. Garbarino, personal communication, March 1988; P Garbarino, personal communication, August 1989.

segment of the industry also is likely to experience substantial growth in the next few years. Such projections for growth have prompted Wall Street analysts to proclaim the waste management industry ‘‘recession proof.

The six largest public U.S. waste management companies in fiscal 1987 reported annual revenues of $5 billion from solid and hazardous waste services. In many instances, these large companies were formed by consolidation and vertical integration, and many are becoming international concerns. For example:

- Western Waste, the fifth largest waste management firm (in terms of 1987 revenues), purchased the routes and other assets of 10 waste hauling companies in fiscal 1987;
- Browning-Ferris Industries, the Nation’s second largest waste management firm, acquired more than 100 solid waste-related businesses; and
- Attwoods PLC, a British company, acquired 12 small Florida waste hauling companies, a medium-sized waste management company in Maryland, and several other waste-related enterprises to make it the fourth largest waste management firm in the United States.

A hint of future trends in waste management can be gleaned from the pages of these companies’ annual reports. All plan continued acquisitions of related businesses to increase capacity for waste treatment and disposal. The industry also is responding to the growing desire in many municipalities to reduce the quantities of waste going to incinerators and landfills (20). For example, a number of companies involved primarily in the waste-to-energy industry have become increasingly involved in materials recovery, both as a means of improving combustion and of keeping up with the changing needs expressed by local governments.

Changing Roles for the Public and the Private Sector

“Grassroots” recyclers have enjoyed revitalized interest, as the public takes a more active role in exploring solutions to MSW problems. Statewide recycling associations formed in the late 1970s have flourished and are helping to educate the citizenry about the benefits of materials recovery. The National Recycling Coalition, with members representing local private recyclers as well as State government officials, has helped increase awareness and facilitate information flow from the local level to the national level. State officials have initiated regional recycling associations, such as the North East Recycling Coalition and the Great Lakes Recycling Coalition, to pursue a variety of cooperative efforts designed to enhance recycling in member States. Such pursuits include cooperative purchasing of products made from recycled materials and development of standards and definitions to become part of a common recycling language. Along with these efforts, many nonprofit recycling centers increased their participation in the MSW system, undertaking community outreach activities and expanding the types of materials they handle.

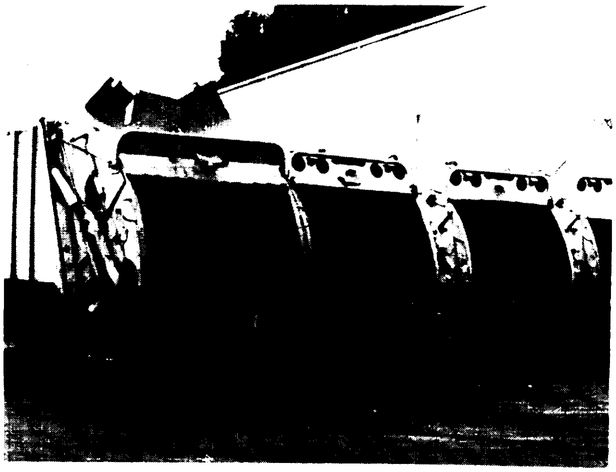


Photo credit: Office of Technology Assessment

In the late 1950s, most communities began using “packer” trucks to collect and compact mixed MSW and then transport it to landfills.

The trend toward increasing materials recovery by the public sector as a means of managing MSW has caused some stress on parts of the existing private infrastructure, however. Traditional scrap dealers, who in the past worked primarily with industrial customers, now must compete with increasing supplies of materials from the residential waste stream. These dealers were once able to act as a sort of ‘‘safety valve, ’ turning the materials supply on and off in response to demand, Their ability to perform this function is changing, however, because the recovery of materials by municipal governments is increasing. Municipal materials recovery is motivated not by price but by avoidance of ever-increasing disposal costs. Therefore, declining commodity prices, which would normally trigger a reduction in supply, can be overshadowed by the need to avoid disposal costs in municipal recycling programs. The existence of a supplier that is not sensitive to prices will put additional pressure on those that are solely motivated by profit.[4] The full effects of these changing waste management trends on the private recycling sector will only be fully realized when recession occurs and materials markets, and prices, shrink.

Some municipalities have attempted to enlist the private scrap sector into the MSW management system. In some cities, existing buy-back and drop-off centers have been included in the overall MSW management plan, either alone or as supplements to curbside recycling programs. In Philadelphia, Pennsylvania, an existing nonprofit buy-back center was used in a pilot recycling program as a materials recovery facility to sort commingled recyclable.

The ownership of MSW management facilities is another factor in transition. Although the trend is toward increased activities to be included in MSW management systems, the operation and sometimes ownership of these activities is often private. As the system becomes more complex and market oriented, municipalities (especially the smaller ones) may be reluctant to assume the primary responsibility for operating a complex business. The large waste management companies that have emerged are sophisticated in the technical aspects of MSW management and financially capable of accepting some of the associated business risks. At the municipal level, the prospect of contracting out increasingly complicated waste management services has become particularly attractive. In some larger metropolitan areas, however, governments may view private scrap dealers as unnecessary intermediaries robbing the public sector of needed revenue.

The private financial sector also has become more involved in MSW management activities. The proliferation of multi-million dollar municipal waste-to-energy facilities in municipalities with limited budgets necessitated the creation of sophisticated financing schemes, and Wall Street brokerage houses have developed a substantial business in creating financing packages for such facilities. In fact, the involvement of large investment houses in the waste-to-energy industry may even have helped reduce the skepticism that many municipal officials had toward this technology. Because the capital requirements for materials recovery facilities are much lower than for incinerators, making financing easier, similar financial sector involvement in recycling may be limited.

As the MSW management infrastructure has evolved, there has been an increasing awareness of the risks associated with management activities and concern over the increased costs associated with improved management methods. The risks and costs associated with MSW practices are two major factors decisionmakers must weigh when devising suitable MSW strategies for their communities.

RISKS ASSOCIATED WITH MSW MANAGEMENT METHODS

Public opposition to the siting of MSW management facilities in part stems from concerns about the potential health and environmental risks associated with these facilities. Potential risks are posed, for example, by:

- emissions and ash from incinerators;
- emissions and leachate from landfills; and
- emissions, effluent, and sludge residues from recycling (including processing and manufacturing facilities).

Some of these are created when the organic portion of MSW (e.g., yard wastes, paper, and plastics) is processed, burned, or decomposed. Others stem from the metals and organic chemicals contained in products discarded in MSW—in 'house-

---

[4] An analogous situation existed in the world copper market, which consists of industrial country suppliers, who are primarily profit-motivated, and of developing country suppliers, who are motivated more by a desire to maintain employment and generate foreign exchange. As copper prices fell during the 1982 recession, developing country suppliers refused to cut back on supply, and in some instances even increased supply to maintain earnings in the face of lower prices. The result was that prices were pushed down even further, to the point where they had been during the Great Depression, a much lower drop than that which occurred in the overall level of economic activity. The price depression experienced by the world copper industry was not matched by that for other industries.

hold hazardous wastes" (e.g., solvents, paints, batteries, and cleansers) and other products (e.g., metal additives in plastics). Non-MSW (e.g., industrial non-hazardous solid waste) discarded at landfills also contributes metals and organic chemicals (chs. 3 and 7). After being discarded, these substances can pose potential risks in any MSW management activity--landfilling, incineration, or recycling (chs. 5,6, and 7).[5] The extent to which any of one of these products or substances contribute to overall risks from MSW management is not clear.

Various public interest and private industry groups have attempted to promote one management method over the other on the basis of comparative risk. However, little effort has been made, even at the Federal level, to **quantitatively** assess the comparative risks posed by **different** MSW management methods. It is beyond the capabilities of current risk assessment efforts to compare risks among management alternatives (e.g., of potential risks associated with landfilling, incineration, or recycling), although comparisons of options within a type of management alternative are possible (e.g., a comparison of landfill designs). OTA has found no quantitative evidence to support a definitive comparison of human health and environmental risks associated with recycling, incineration, and landfilling.

Quantitative estimation and comparison of the relative risks associated with different management methods is difficult, in part because of problems inherent in risk assessment methodologies and in part because of data deficiencies. For example, it is clear that some potential environmental risks are associated with all MSW management methods because all processing, treatment, or disposal methods result in some type of waste byproduct. Many proponents of recycling contend that it poses fewer risks than alternative MSW management methods. However, given current data, it is not possible to quantitatively determine whether recycling produces more or less pollutants, or poses greater or fewer risks, per ton of material processed than do incineration or landfilling.[6] To compare the overall potential risks quantitatively, an in-depth analysis would have to assess the location of all facilities, all waste products from manufacturing and management facilities, exposure pathways and dosages, and potentially affected populations. Obviously, this would be an extremely expensive and time-consuming task.

Some qualitative comparisons can still be attempted, however. Many secondary materials can be recycled several times before their ultimate disposal (and some, such as glass and aluminum, can be recycled indefinitely), thus decreasing the use of virgin materials. Since recycling a product avoids the production of pollutants from both manufacturing a new product and landfilling or incinerating the old product, recycling materials several times would seem to produce less pollutants on an overall basis than would incineration or landfilling.

A second question that can be addressed concerns the relative risks **within a** given method. Most risk assessments have focused on the relative risks within a single management method. Given these risk assessment methodologies and available data, it is possible to make comparisons within a particular method and indicate which pollutants are of greatest concern for those methods. The relative reductions in risk that might be achieved by retrofitting older facilities or designing new facilities with different controls can also be estimated.

For example, pollutants of concern in incinerator emissions include organic chemicals such as dioxins and metals such as mercury. Human exposure to these substances may be greater through food chain pathways than through inhalation pathways (ch. 6). However, there is considerable debate about the extent of exposure and subsequent risks associated with these pollutants and these pathways. Nevertheless, it is clear that the risks associated with new, well-operated incinerators (e.g., with a scrubber/ fabric filter system and computerized combustion) are substantially lower, in some cases orders of magnitude lower, than those associated with old facilities. Moreover, the risks associated with emis-

---

[5] Defining exactly what is toxic is an enormous task beyond the scope of this report. OTA discusses these issues here on the resumption that when substances are identified as posing risks, then attempts should be made 10 get them out of the waste stream,

[6] A comparison can be made, though, between manufacturing processes using secondary materials (i.e., those recovered from the waste stream) and those using virgin materials. In many instances, using secondary materials to produce a given product produces less pollutants and saves energy in comparison with extracting virgin materials and subsequently manufacturing the same product (ch. 5).

sions from new incinerators appear to be within the range of risks allowed under regulations for other activities (e.g., drinking water standards). One consequence of better emissions controls, however, is that the resulting ash residues have higher concentrations of some substances. In particular, there is considerable controversy about the metals contained in the ash and the extent to which they might leach into groundwater (ch. 6).

Similar environmental problems can be associated with recycling, particularly the actual processing of collected secondary materials, and with landfilling. But as was the case with incinerators, newer recycling and landfill facilities offer greatly improved performance over older facilities. Composite liners, groundwater monitoring, and gas collection systems, for example, make today's landfills safer than in the past.

Many older facilities will continue to operate for several decades, thus national-scale analyses of the overall risks from MSW management cannot be made on the basis of newer facilities alone. The relative risks among available management options for particular communities could vary greatly depending on local conditions, raising serious questions about whether a national-scale analysis would be worth the cost. Most decisionmakers agree that standards for different management methods should be developed to ensure adequate protection for human health and the environment. The prevention and materials management approach to MSW suggested by OTA is predicated on the assumption that all facilities comply with these standards.

COSTS OF MSW MANAGEMENT

Increased concern about risk coupled with the increased complexity in MSW management combine to increase its overall cost. Although MSW management in the past typically played a small part in municipal budgets, costs are increasing more rapidly than many other budget items. As a result, municipal governments across the Nation are focusing more attention on the costs of managing MSW and seeking ways to improve the efficiency of the system.

As local officials plan for future MSW management, a key question they face is which management method or combination of methods is most economical for their community. Varying social, economic, and demographic conditions will make different approaches best for different communities. This is already evident in the multiplicity and variety of MSW management systems now operating throughout the country. In communities where disposal capacity problems have not surfaced, little attention is generally paid to the costs of trash collection and disposal. Often, these items are not broken out separately in the municipal budget and may be combined with items such as street cleaning. It is not uncommon to find that the municipal government official responsible for solid waste disposal knows little about the costs and characteristics of solid waste in the community.

To collect information on a variety of cities and counties across the Nation, OTA conducted a limited survey on the costs of MSW management. In addition, a cost estimation model was constructed for OTA by Energy Systems Research Group (ESRG) of Boston to examine the sensitivity of system costs to various relevant factors (box 2-B). This information provides the basis for the discussion in this section.

Solid Waste Management Costs in Perspective

Although MSW management costs are increasing, they represent a relatively small portion of most municipal budgets and an even smaller portion of the average family's budget. Among the 41 cities and counties responding to OTA's survey, the MSW budget ranged from 0.1 to 19.2 percent of the total municipal budget, but averaged only about 5 percent. Based on the data, annual MSW expenditures per person ranged from $6to$130, averaging about $60. Thus the average family covered in the survey typically spends less than 1 percent of its income on MSW management.[7] Data from the Bureau of the Census (16) also indicate that MSW has not been a major budget item for cities and counties. For the majority of communities for which information is reported to the Bureau, the portion of the municipal

---

[7] The median family income in the United States in 1987 was $31,000 as estimated by the U.S. Bureau of the Census (17).

Box 2-B--OTA Survey and Computer Model of MSW Management Costs

To gather information about the costs of waste management practices around the United States, OTA surveyed 44 cities and counties (see table 2-l). Each prospective respondent was contacted by phone and by mail, and 93 percent completed the survey. The survey was not designed to represent a statistically significant sample of nationwide waste management practices. Rather, the survey was an attempt to increase awareness about the variation among municipalities in the level of attention to MSW management, the distribution in costs, and the problems encountered.

Those surveyed were chosen to provide geographic and demographic diversity and to encompass a range of MSW management strategies, from landfill only, to waste-to-energy incineration and landfill, to intensive recycling. Ownership of landfills and incinerators was relatively evenly divided between public and private, with counties tending toward more public ownership of facilities than cities. Among the cities, 52 percent of the landfills and 33 percent of the incinerators were publicly owned. By comparison, counties owned 70 percent of the landfills and 80 percent of the incinerators that they used. Residential trash collection was undertaken by municipal crews in 31 communities, by contractors in 16, and solely by residents or private haulers in 5.

Of the *41* cities and counties responding to the survey, 11 reported having no residential recycling program of any type. Of those with recycling programs, 19 reported curbside recycling programs (5 of which were mandatory), 26 had dropoff programs, and 18 had buy-back programs. Only 5 communities reported having some type of private curbside program, while 19 of the dropoff and all but one of the buy-back programs were privately operated. Comporting programs were reported in 19 of the communities surveyed, and 13 of the communities had household hazardous waste programs. Fourteen of the respondents used some type of avoided cost calculation to justify their recycling program.

In addition to the survey, OTA contracted with Energy Systems Research Group, Inc., to develop a computer model to help understand the costs of MSW management alternatives. Because accounting methods differ widely and hundreds of factors have a bearing on system costs, cost data available from different public and private sources are not easily comparable. The model calculates the costs of various management methods under a variety of different demographic and economic situations. The model is not designed to determine the “optimal’ system configuration. Its results thus depend on local or site-specific details. OTA, therefore, has not used the model to provide generic comparisons of the costs of different management methods. Instead, the model is used to show the effects of changing key parameters on system costs. All costs are reported in 1988 dollars unless otherwise noted.

The base case for all analyses with this model includes the following conditions:

- a municipality with a population of 500,000,
- *75* percent of the population lives in single-family housing,
- residential waste generation is 2.4 pounds/person,
- commercial waste generation is 1.2 pounds/person,
- commercial collection is paid for by the commercial generators, and
- all facilities are designed to accommodate commercial waste.

In the model, the landfill is assumed to be state-of-the-art, with leachate and methane collection systems, liner systems, and monitoring wells. Land costs are relatively low, $1,500 per acre, and transport distance from collection point to the landfill averages 15 miles. The cost includes closure and post closure expenses.

The incinerator included in the model’s calculations uses advanced pollution controls (i.e., wet scrubber and baghouse filter) and generates electricity, which is sold at a rate of $0.06 per kWh. Ash is disposed of in a monofill with a double composite liner system and a leachate collection system. The incinerator produces ash equal to 23 percent by weight of the waste burned. Residential wastes not sent to the incinerator include major appliances, tree stumps, and tires; these wastes are sent to the MSW landfill.

Table 2-1—List of Cities and Counties Surveyed

West:
Seattle, WA
King County, WA
Yakima, WA
Marion County, OR
Portland, OR
San Francisco, CA
Davis, CA
San Jose, CA
Los Angeles, CA

Rocky Mountain/Southwest
Denver, CO
Boulder, CO
Livingston (Park County), MT
Pocatello (Bannock County, ID
Albuquerque, NM
Phoenix, AZ
Prescott, AZ
Austin, TX
San Antonio, TX
Tulsa, OK

Midwest/Central
Minneapolis, MN
Chicago, IL
Carbondale, IL
Kalamazoo, MI
Springfield, MO
Waukesha County, WI
Cincinnati, OH

Southeast
Tampa (Hillsborough County), FL
St. Petersburg (Pinellas County), FL
Fairfax County, VA
Shreveport, LA
Charlotte (Mecklinburg County), NC
Chattanooga, TN
Atlanta (Gwinnett County), GA

Northeast
Philadelphia, PA
Newark (Essex County), NJ
Cape May County, NJ
Boston, MA
Marblehead, MA
Somerville, MA
Hamburg, NY
New York, NY
Delaware Solid Waste Authority, DE
Montgomery County, MD
Peterborough, NH

budget allocated to MSW appears to be less than 10 percent of the total.[8]

It is not surprising, therefore, that this budget item has received little attention in the past. In fact, only about half of the communities responding to OTA's survey charged fees directly related to trash disposal costs; the rest paid the collection and disposal bill out of general revenues, bond funds, grants, or some combination of these, somewhat obscuring MSW costs within the budget. The level of detail in the survey responses indicated that the various components of MSW costs generally are not well-defined or accounted for. This was particularly true of recycling programs. Of the 19 respondents who reported having curbside residential recycling programs, only 8 had cost information on the program and 11 had an estimate of the amount of materials collected. Only six communities were able to report a separate quantity of commercial waste recovered, although it is likely that commercial materials recovery occurs everywhere. Ten of the respondents incinerated a portion of their waste, but only half of those were able to report on the capital and operating costs associated with that option. (All reported a tipping fee, however.) Other analysts seeking detailed MSW cost information from local governments have noted similar difficulties (1,6,13,15).

Although it is not possible to draw broad conclusions from a small survey, the responses indicated that definitions and calculation methods are a problem, particularly for recycling. With few exceptions, most of the communities were not aware of the

---

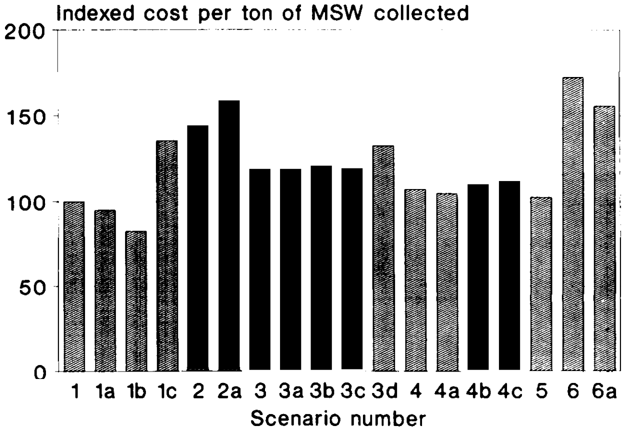
[8] The Bureau of the Census reports data on State and local government expenditures in the "Government Finances" series (16). Solid waste expenditures are reported as 'sanitation other than sewerage, Average expenditures as reported in this source (1986, latest available) are actually less than 3 percent of total expenditures.

amounts of materials being recovered from the MSW stream or the costs associated with that recovery. As recycling programs become more elaborate, and more commonplace, it is likely that communities will become more aware of their costs and effectiveness. Such an awareness is essential for the efficient operation of a recycling program as well as a MS W management system.

Results from the ESRG model indicate that a variety of factors can have a significant impact on the overall costs of MSW management. For each MSW management method, factors were chosen for sensitivity tests based on the generally accepted knowledge about the important cost factors. Although an exhaustive sensitivity analysis was not performed for each MSW management method, OTA attempted to analyze those factors that most often come into question when discussing costs. For example, OTA examined the sensitivity of landfill costs to pollution controls and transportation distances and of recycling costs to the efficiency of the collection process and the prices obtained for the materials collected. Figure 2-1 shows the variation in estimated costs for different MSW management scenarios. Table 2-2 describes each major scenario tested. As shown in the figure, if existing landfill costs are relatively low (scenarios 1-1 b) then system costs will increase when additional MSW management alternatives are added. Under the model's assumptions, waste-to-energy incineration (scenarios 2 and 2a) increases costs by a larger percentage than recycling programs (scenarios 3-3d and 4-4c). However, when landfill costs are extremely high (scenario 6), the addition of alternative management methods (in this case, recycling and comporting) can reduce overall system costs by avoiding the costs of landfilling (scenario 6a).

This model, while of course used here in hypothetical scenarios that are not applicable to any particular community, highlights the importance of close attention to every cost element of the MSW management system. The more complex the system, the more important it becomes to carefully monitor each cost component, Increased complexity brings increased costs. Improved cost accounting methods and practices can help all municipalities control the expected further rise in MSW management costs.

Figure 2-1--Compariaon of MSW Management Costs For Selected Model Scenarios



NOTE: The cost of scenario 1 is set equal to 100, and then the costs of all other scenarios are compared with scenario 1. For example, the cost of scenario 2 is approximately 45 percent greater than the cost of scenario 1. See Table 2-1 for scenario descriptions.

SOURCE: Office of Technology Assessment, 1989.

Landfills: The Indispensable Option

Survey Results

Landfills were relied on exclusively by 13 of the survey's respondents.[9] Per-capita solid waste management costs were relatively low for these respondents, ranging from $6 to $44 and averaging about $25. *On* a per ton basis, solid waste management costs were below $70 for these communities, and landfill disposal costs accounted for 12 percent or less of the total.

Fifteen communities provided capital or operating cost information on landfills. Operating costs ranged from less than $3 to about $40 per ton, with 13 of the 15 respondents reporting costs of $12 or less; capital costs were not reported on a comparable basis. The highest operating costs were for a landfill with state-of-the-art technology, including a triple liner system, leachate collection systems, and monitoring wells.

---

[9] This figure includes those respondents who reported that materials recovery occurred, but who did not know the exact amount. Some of these communities have recycling programs, but it was assumed that because they are not aware of the amounts recycled, then recycling is not considered a part of their MSW management strategy and no costs are incurred.

Table 2-2—Description of Model Scenarios for MSW Management Cost Comparisons

Scenario	Collection	Incineration	Recycling	Composting	Transfer	Landfilling
1	Mixed waste in 31 cu. yd. packer trucks 75% single family 25% multi-family					Land cost = $1,500/acre Includes composite liner, leachate collection, monitoring wells, methane collection, methane price = $3/1,000 cu.ft.
1a	Same as 1 except: 50% single family 50% multi-family					Same as 1
1b	Same as					Landfill has no pollution controls, no methane recovery
c	as				Transfer with 50-mi. shipping distance Shipping cost = 20 cents/ton mile Same as 1	Same as 1
2	Same as	1,100 TPD capacity site-erected mass burn (cost $122 million) 100% of energy used to generate electricity Electricity price = 6 cents/kWh Ash disposed in monofill with double composite liners, leachate collection, monitoring wells				Materials landfilled include discarded appliances, stumps, tires
2a	as	Same as 2 except electricity price = 3 cents/kWh				Same as 2
3	Mixed waste same as 1 Recyclables collected in 15 cu.yd. capacity compartmentalized vehicles Residential diversion rate = 4.5%		Curbside separation; Recyclables placed presorted at curb in stackable containers Materials in single family collection: ONP, glass, Al. Multi-family collection: ONP Processing facility densifies and bales materials for market			Same as
3a	Same as 3 except Residential diversion rate = 6.8% Participation and capture rates = commingled program		Same as 3			Same as
3b	Same as 3 except Residential Diversion Rate = 6.4% Participation and capture increase by 10 percentage points		Same as 3			Same as

3c . . . . Same as 3 except for deposit on glass, Al, and plastic beverage containers that removes them from waste stream Waste generated is reduced by 6%		same as 3			Same as 1
3d . . . . Same as 3 except number of stops per hour for collection of recyclables is cut in half	Same as 3				Same as 1
4 . . . . Mixed waste same as 1 Recyclables collected in 20 cu. yd. closed body recycling vehicle Residential diversion rate= 8.0%		Comingled recyclable placed in single 0.06 cu. yd. container at curb Materials in single family collection: ONP, glass, Al, Fe. Multi-family: ONP, glass, Al, Fe Processing facility separates cleans, densifies, and bales materials for market			Same as 1
4a . . . . Same= 4 except participation and capture increase by 10 percentage points Residential diversion rate. 10.9%		same as 4			Same as 1
4b . . . . Same as 4 except for deposit on Al, glass, and plastic beverage containers that removes them from waste stream Waste generated reduced by 6%		same as 4			Same as 1
4c . . . . Same as 4 except number of stops per hour for collection of recycleables is cut in half		Same as 4			Same as 1
5 . . . . Mixed waste same as 1 Yard waste collected separatly in same collection vehicle Residential diversion rate = 9.3%			Leaves and other yard waste placed in paper bags at curb 20 weeks per year Comporting done at 2 10-acre sites Compost sold for $3/cu. yd.		Same as 1
6 . . . . Same as 1				same as 1c	Land cost = $5,000/acre Double capital costs and most operating costs
6a . . . . Mixed waste same as 1 Recyclables same as 4 except participation and capture = 90% Yard waste same as 5 Residential diversion rate = 33.0%		same as 4	Same as 5	Same as 1c	Same as 6

KEY: TPD = tons per day kWh = kilowatt hour; Residential diversion rate= percentage of residential waste diverted from landfill by recycling or composting; ONP = old newspaper; Al = aluminum; Fe= iron and steel.

SOURCE: Office of Technology Assessment, 1989.

Model Results

To understand how different factors affect landfill costs, OTA used the ESRG model. Model results are for a hypothetical scenario only and should not be interpreted as applying to any particular community's situation. Costs can vary considerably, depending on site-specific conditions. As noted above, OTA's intent is to indicate the types of factors that are likely to have the greatest bearing on costs, not to predict actual costs in real situations. For this analysis, OTA examined the effects of collection efficiency, transportation distances, and pollution controls on landfilling costs.

For a landfill-only scenario (scenario 1), the model calculated a total cost to the municipality for MSW collection and disposal of $58 per ton, $18 of which is accounted for by landfill disposal costs.[10] By comparison, if the landfill used by the municipality had no pollution controls, total cost would have been $48 per ton, with only $8 attributed to landfill disposal (scenario lb). In scenario 1, therefore, pollution controls add about $10 to the cost per ton of waste disposed. The $8 estimated for landfill disposal with no pollution controls is consistent with the landfill operating costs reported in OTA's survey, most of which were less than $12.

It is interesting to note that the addition of a transfer station (where MSW is transferred from packer trucks to larger trucks or rail cars for long hauls) to the hypothetical municipality, with a subsequent 50-mile transport distance to a landfill, increased total MSW costs to $78 per ton, with $20 per ton added for the transfer and long haul (scenario 1c). Thus the model indicates that the need for transfer and long haul adds more to the landfilling cost than pollution controls. In the real world, these transfer and transportation costs may even be greater in some situations. For example, one community in OTA's survey reported an expected combined transfer and disposal cost of $44 per ton to support a new transfer, transport, and landfill system (not including collection) to be developed to dispose of waste 140 miles away (7).

Collection costs, the other main component of OTA's model scenario, are primarily dependent on truck and operator efficiency. Ignoring problems caused by congestion and one-way streets common in high population density areas, the model indicates that collection can take place more efficiently in those areas. For example, by changing the hypothetical municipality from 75 to 50 percent single-family housing, overall residential collection costs were reduced by about $3 per ton (scenario lb). By comparison, a 50-percent increase in stops per hour, which could be realized with higher density housing, reduced average residential collection costs by $8 per ton. The model also estimated that a similar cost saving ($7 per ton) will result if the amount of trash picked up per stop is increased by 50 percent.

Incineration and Landfilling

Survey Results

Incinerators were used by 12 (30 percent) of the survey respondents to dispose of anywhere from 6 to 90 percent of their waste; detailed information was provided for only 10 of these sites. In communities with operating incinerators, per-capita MSW management expenditures ranged from $21 to $82, and averaged $46. Total MSW management costs per ton, available for only 4 of the 12 municipalities, ranged from $77 to $230 per ton. The share of these total costs attributed to incinerator operation ranged from 17 to 55 percent.

Capital and operating cost information on incinerators was available for 6 of the 12 communities. Operating costs ranged from $18 to $50 per ton, and capital costs ranged from $3 million for a 72-ton-per-day (TPD) modular incinerator to $80 million for a 1,200-TPD mass bum incinerator. The average tipping fee for the five operating incinerators for which that information was reported was $31. Two of the incinerators increased tipping fees by about $10 per ton after the survey was completed. One increase was in response to lower-than-expected revenues from the sale of steam generated at the plant.

In addition to these existing incinerators, four respondents are in the process of building new incinerators, all of which are expected to be operational by 1991. Two reported expected tipping fees

---

[10] **This estimate is consistent with other** recent landfill **cost** estimates. For example, one study (3) estimated total landfill **costs** for a state-of-the-art landfill at $11.25 per **ton** in 1986 dollars. 'his study also estimated that landfill development cost $4.23 per ton in 1975 and **will** cost $18.30 per ton in 1990,

in the $75 to $80 range in the first year; no information was available for the other two.

In general, the capital costs reported in OTA's survey were within the range of published data. The 1986-87 Resource Recovery Yearbook (4) reported adjusted capital costs (in 1986 dollars) of advanced-planned and existing incinerators ranging from $250,000 to $429 million, and averaging $58 million. Capital costs of modular plants were reported as below $10 million (1986 dollars). Average operating and maintenance costs were reported in the Yearbook as $22 per ton, which is within the range of OTA's survey results.

In OTA's survey, only six of the communities using incinerators reported on revenues from energy generation; the two newest incinerators generated electricity, and four others generated steam. Revenues from the sale of this energy averaged about $10 per ton of waste incinerated per day.

The amount of ash generated from these incineration facilities ranged from 11 to 31 percent by weight of the MSW burned, and averaged 20 percent. Ash disposal costs were reported for only three incinerators and varied widely (i.e., $4.50,$28, and $49 per ton).

Of 12 communities using incinerators, 9 reported materials recovery from some type of recycling program (including 2 recovering metals from incinerator ash). Five recovered less than 5 percent from the waste stream, three recovered between 10 and 20 percent, and one recovered 34 percent.

Model Results

The cost of building and operating an incinerator are dependent on the same factors affecting the cost of any large industrial facility—materials, engineering, labor, and financing. One of the most attractive and different features of modem incinerators, however, is that they can recover and sell energy. Although a multitude of factors can affect the costs of incineration, the revenues from electricity sales are often considered one of the most important factors in the viability of an incinerator operation. This analysis of incinerator costs therefore focuses on changes in electricity revenues.

Using the assumptions described in box 2-B, the model calculated the costs for a site-erected mass bum incinerator, an ash monofill, and an MSW landfill. In this hypothetical scenario (scenario 2), 13,000 tons of residential waste are sent to the MSW landfill, compared with 214,000 tons in the landfill only scenario. The use of the incinerator reduced the amount of waste landfilled by 74 percent (even accounting for the ash landfilled) and increased system costs by 45 percent.

Given these assumptions, the model calculated a total MSW system cost of $83 per ton of residential waste collected. The capital cost of the incinerator was $121.8 million (with a capacity of 1,100 TPD), and net operating costs (including debt service, ash disposal, and accounting for electricity revenues) amounted to $45 per ton of waste burned. Electricity revenues amounted to $10 million annually.[11] On a percentage basis, collection costs accounted for 48 percent of total MSW system costs, incineration accounted for 51 percent, and MSW landfilling accounted for 1 percent.

To determine the sensitivity of system costs to electricity revenues, the electricity rate received by the incinerator in the model scenario was cut by half, to $0.03 per kWh (scenario 2a). The model estimated that electricity revenues were reduced to $5 million annually, and net operating costs for the incinerator increased from $45 to $61 per ton of waste burned. The drop in electricity revenues caused a substantial increase in the estimated cost of incineration per ton of residential waste collected, which jumped from $43 to $58 and thus accounted for 63 percent of total system costs. Total system costs estimated for this scenario increased to $92 per ton of residential waste collected, compared with costs of $83 per ton under the original incineration scenario.

As mentioned above, construction costs for new waste-to-energy facilities have been reported to reach $400 million or more for large facilities (3,000 TPD). Research undertaken for the model indicates that significant economies of scale do not exist for these facilities-the capital and operating cost per ton is relatively constant over a range of capacities. This has also been reported by other investigators (5). However, running a plant below its operating

---

[11] This estimated revenue was significantly higher than the energy revenues reported in the survey on a per ton of waste burned per day basis (i.e., $25 per ton per day compared with $10 per ton per day).

capacity could increase per ton costs substantiality because the fixed costs that must be covered, regardless of throughput, are a large proportion of total costs. The costs presented here only represent a reasonable hypothetical plant; financing mechanisms, as well as local economic conditions, might produce significantly different costs.

Materials Recovery: The Moving Target

The characteristics of existing community recycling programs are as varied as the communities themselves. Thus it is difficult to generalize about the elements of a successful recycling program. The success of a recycling program, more aptly called a materials recovery program, can be as dependent on geography and demographics as it is on choosing the right collection equipment.

Early experience with intensive community recycling programs shows that the education and income level of the population can be positively related to participation rates (11). This finding is supported by pilot programs in a low-income community in Illinois (14) and in several areas in Rhode Island (8). OTA's survey did not collect demographic information, and it therefore has not verified these conclusions regarding the effects of education or income on recycling programs.

Other factors also have an impact on the success of recycling programs. Convenience and consistency are both crucial to maintain high citizen participation; therefore, weekly curbside recyclable pickup on the same day as trash pickup is likely to result in higher materials recovery than monthly pickup on a separate day or a drop-off program (10). The number of separations required of the resident can also affect recovery rates. Fewer separations require less space at the residence for storage and can reduce collection time for pick-up crews, a crucial factor in the recycling cost equation. In addition, how commercial establishments and high-density apartment buildings are handled greatly affect a program's overall success.

The commitment of governments to recycling also affects the recycling rate; mandatory recycling programs achieve better recovery rates than voluntary, although exceptions do exist (10). Similarly, municipally provided recycling bins and good public outreach programs both can have positive effects on recovery rates (14).

Survey Results

Respondents to OTA's survey reported a variety of recycling programs; however, 6 of the 41 specifically reported that no materials were reclaimed from their MSW and 11 reported having no formal recycling program. Of the remaining 24 communities, 5 had mandatory curbside recycling and 15 had voluntary curbside programs. Another 4 cities planned to start voluntary programs in the near future. Drop-off programs were reported in 26 communities, and buy-back programs were reported in 18. In addition, 19 communities had white goods recycling programs, 19 had comporting programs, 13 had household hazardous waste collection programs, 10 had tire collection programs, 13 had some type of battery collection program, and 21 had waste oil programs. At least one-third of these programs were privately operated, which is no doubt one of the major reasons that information is sparse on the amounts of materials collected.

Only about 10 communities were able to report information on materials collected and revenues obtained from the sale of recyclable. The materials collected and number of programs in which they are included were as follows:

Aluminum	10
Glass	10
Newspaper	9
Steel	8
Corrugated	4
Office paper	3
Mixed paper	3
PET	3

Revenues for materials showed surprising variation. For example, 1988 aluminum revenues varied from $12 per ton for aluminum commingled with glass (paid by intermediate processor), to $1,075 per ton for aluminum collected in a curbside separation program, to $1,300 per ton for aluminum sold by a drop-off center, to a projected $1,340 per ton for aluminum collected in a commingled program and processed in an intermediate processing facility. Flint glass revenues for drop-off programs varied from $20 to $60 per ton.

Photo credit: Office of Technology Assessment

Consumers sometimes can leave separated materials at igloos or other containers placed in conspicuous areas by the community or firm running a recycling program. These drop-off programs do not pay consumers for the materials, unlike buy-back programs.

For the curbside recycling programs, reported operating costs minus materials revenues varied from $26 to$110 per ton, and averaged $62 per ton. Interestingly, both the least expensive and the most expensive of these programs was a voluntary commingled collection program. Trash collection and disposal costs for those communities with curbside recycling programs ranged from $44 to $220 per ton, and averaged $98 per ton. Per-capita MSW expenditures for these communities averaged $42.

Information on other types of recycling programs was sparse. One drop-off center reported operating costs, net of revenues, at $32 per ton for 1986. One buy-back center reported operating costs after revenues of about $25 per ton. In many instances, the costs reported were only rough calculations because detailed statistics are often not kept. Sometimes the processing of recyclable is contracted out, and the contracting community does not require the processor to provide detailed reports on materials sold and revenues generated. Also, definitions of what is to be included in the recycling cost calculation vary by community. As a result, these reported costs must be viewed with caution. They are provided to indicate the range of variation that can be encountered in communities with different recycling scenarios.

Model Results

OTA's model can provide some insight into the specific cost components of a recycling program. In terms of economics, the success of recycling programs depends primarily on the efficiency of the collection process, the level of participation by residents, and the prices obtained for the materials collected. Using the ESRG model, each of these elements can be examined separately to determine its effects on recycling costs.

Collection efficiency depends on the number of set-outs (i.e., MSW pick-up sites) that can be served per hour and how often the collection truck must return to the unloading area. Factors determining set-outs served per hour include truck design, number in crew, housing density, traffic congestion, and road conditions. Factors affecting the frequency of return trips include family size, waste generation rate, recovery rate, and the mix of recyclable materials.

Curbside Collection** of **Separated and Commingled Materials-The first general scenario for recycling used in the model was a curbside separation program serving the community outlined in box 2-B. The materials included in the single-family housing program were newspapers, glass containers, and aluminum containers. Newspapers also were collected in multi-family housing areas. The materials collected in the program were assumed to be processed to a limited extent at a central facility sized to process commercial recyclable as well. However, the municipality in the scenario did not pay for collection and processing of the commercial recyclable. All MSW not recovered for recycling was sent to a landfill for disposal.

The model calculated costs on a systems cost basis-all per-ton costs were figured on total residential MSW collected. Because the community in this example paid for collection, processing, and landfilling, it is appropriate to spread all the costs over the total amount of waste that must be managed. In this example, the community collected 214,314 tons of MSW, of which 9,691 tons were recovered for recycling (4.5 percent of residential waste collected) (scenario 3). Using the accounting method described above, the model estimated that the total MSW management cost per ton of material collected amounted to $68.81, of which trash collection accounted for 58 percent, landfilling for 25 percent, recyclable collection for 16 percent, and recyclable processing for 1 percent. An additional scenario was created in which participation and capture rates for the materials collected were set to equal those assumed for a curbside commingled program (i.e., they are somewhat higher). The amount of recyclable collected in this version was 14,638 tons (scenario 3a). The model estimated that total system costs in this scenario were reduced slightly to $68.69 per ton of material collected, with the major savings resulting from the increased diversion of material from the landfill and the lower total landfilling cost.

Another scenario was created to model a curbside commingled recycling program (scenario 4). This program was assumed to have higher participation and capture rates than the original curbside separation scenario, because fewer separations are required; materials prices were assumed to be the same. Materials collected from both single and multi-family households included newspaper, glass, aluminum, and ferrous containers, which were assumed to be processed in a materials recovery facility. In this scenario the community also collected a total of 214,314 tons of MSW, but 17,236 tons were recovered for recycling (8 percent of residential waste collected). The total MSW management cost for this scenario was estimated by the model to be $61.82 per ton, of which trash collection accounted for 62 percent, landfilling for 28 percent, recyclable collection for 9 percent, and recyclable processing for 1 percent. The increased recycling efficiencies in this scenario compared with the curbside separation scenario are realized by more productive collection of recyclables—more material is collected per stop, with no decrease in pickups per hour. Overall system costs for recyclable collection in this scenario were estimated at about half those for the model's curbside separation recycling scenario.

One important component of the total cost of any collection system, according to the model, is the time required for a fully loaded vehicle to unload and return to the collection route. For example, increasing the distance the commingled collection vehicle traveled to drop off recyclable from 5 to 10 miles increased recyclable collection costs by an estimated 2 percent. Much more important, however, is the number of pickups that the collection vehicle is able to make in a fixed time period (21). Reducing recyclable pickups per hour by one half (while holding the amount of recyclable picked up per household) increased overall system recyclable collection costs by an estimated 57 percent for the hypothetical commingled program (scenario 4c) and by 71 percent for the curbside separation program (scenario 3d).

According to the model, participation and capture rates also affect the efficiency of a recycling program. Increasing participation and capture rates by 10 percentage points resulted in a 21 percent decrease in collection costs per ton of recyclable collected for the curbside separation program (scenario 3b) and in a 25 percent decrease for the commingled program (scenario 4a). Again, the increased productivity of the collection vehicle was responsible for the cost savings.

The revenues obtained from the sale of the recyclable are also an important factor in recycling program costs. Using the model's basic scenarios, revenues from residential recyclable amounted to $591,000 for the curbside separation program and to

$1,047,000 for the commingled program. When materials prices in the model were cut in half, revenues also declined by half. For the curbside recycling processing facility, this caused an increase in net processing costs from $14.67 per ton of recyclable processed to $45.16 per ton. For the commingled recycling materials recovery facility, net processing costs increased from $8.10 per ton of recyclable processed to $38.47 per ton. In terms of total system costs, the effect was less, but still significant. Total system costs per ton of waste collected increased by 2 percent ($1.38) in the curbside program and by 4 percent ($2.44) in the commingled program. Total system costs were more affected in the commingled program mainly because larger amounts of materials were processed. In general, the model indicates that the proportional effect of decreased prices on system costs will increase as the amount of material recycled increases.

Beverage Container Deposits and Residential Recycling-One often-asked question is, how will beverage container deposit systems affect the economics of municipal recycling programs? To analyze this question, a scenario was created to simulate the effects of requiring a deposit on all glass, aluminum, and plastic beverage containers, assuming that this resulted in the capture of 80 percent of those containers. Given the waste composition assumed in the model, an estimated 40 percent of all the glass containers, 60 percent of all aluminum containers, and 40 percent of all plastic containers were recovered in the deposit system and were not available for curbside recycling or trash collection. The scenario changes the waste stream because deposit items do not enter it and thus the waste stream was only 94 percent as large as in the original scenario. This change had effects on both curbside and commingled recycling programs.

Because deposit systems reduce the amount of materials collected for recycling, the cost efficiency of municipal recycling programs is diminished. The collection cost per ton of recyclable collected in the model's curbside separation program increased by 23 percent when a deposit system was operating (scenario 3c). The net cost of materials processing increased by more than 200 percent with the deposit system as a result of both decreased efficiency of equipment use and decreased revenues. For the commingled recycling program, the collection cost per ton of recyclable collected increased by 13 percent and the net cost per ton for materials processing increased by more than 400 percent with the deposit system (scenario 4b). On a system cost basis the deposit system increased overall costs per ton by 0.3 percent for the curbside separation recycling scenario and by 3 percent for the commingled recycling scenario.

One of the most important factors affecting these costs is aluminum revenues. Because aluminum revenues are potentially the biggest profit earner for most processing facilities because of their high value per ton, including aluminum beverage containers in the deposit system sharply reduces the revenues of those facilities. In its beverage container redemption system, California has dealt with this problem by allowing the processing facilities to receive the redemption value for the containers they collect to augment their revenues. In addition, their system includes a processing fee that must be paid by the manufacturer of the product to ensure that recycling can be carried out economically (ch. 8),

The overall effect of a deposit system on the costs of MSW management is to reduce total costs (but not necessarily per-ton costs) to the public sector because less waste is generated that must be managed by the municipality. The costs of managing the used beverage container portion of the waste stream is transferred to the consumer, the retailer, and the beverage industry. (In the California example, the State government incurs some costs in administering the program.) OTA did not attempt to determine what those costs are and how they compare with the costs to the municipality of managing used beverage container wastes.

Separate ***Collection and Comporting of Yard*** Waste-Comporting is another MSW management method that has received increased attention and has been included with many recycling programs. The comporting scenario analyzed by the model included the collection of residential leaves, grass clippings, and small brush (scenario 5). This scenario assumed that the waste was set out in paper bags and picked up by trash collection vehicles on a separate route; the compost facility was assumed to be centrally located and to sell the compost for $3 per cubic yard; the participation rates for the program were set at 70 percent for leaves and 50 percent for grass and brush; and capture rates were 80 percent for both. Using these assumptions, the model estimated that the yard waste comporting program collected 19,855 tons each year, about 9 percent of the residential waste stream.

The total cost per ton of residential waste collected for this configuration was $59.27, about 2 percent more than the total cost per ton for the landfill only scenario. Collection was a major factor in the costs of the comporting program. For the paper bag comporting program, collection cost about $40 per ton of yard waste collected and processing cost only about $4.50 per ton of yard waste collected. On a system cost basis, the comporting program amounted to only about 7 percent of the total cost per ton of waste collected. According to the model, comporting programs will have a similar effect on a system that includes a recycling program.

Recycling and Comporting in a Community With High Landfill Costs—Different scenarios must be compared carefully because many assumptions must be made to run the model. Changing these assumptions can result in very different cost configurations. OTA attempted to choose realistic assumptions but they were not necessarily representative of the entire range of possibilities. Many communities, of course, will differ from these assumptions. One clear difference may be landfill costs because the model used relatively low landfill costs in its base scenarios.

To examine the effects of high landfill costs, OTA created another scenario that increased land costs from $1,500 to $5,000 per acre, substantially increased most capital and operating costs, and added a transfer station with a 50-mile haul to the landfill (scenario 6). This scenario increased total system costs to $99 per ton of waste collected for a MSW management system with a transfer station and landfill only, compared with the original landfill only scenario cost of $58 per ton. The landfill and transfer costs amounted to about 60 percent of total system costs in this high cost scenario.

In another run of the model, the high landfill cost scenario was modified to add a commingled recycling program and yard waste comporting in addition to the transfer station and landfill (scenario 6a). This scenario made very optimistic assumptions about the success of the recycling and comporting programs. Participation and capture rates equaled 90 percent for both, resulting in 33 percent of the waste stream being diverted from the transfer station and landfill. Avoiding this costly part of the MSW management system for this large a portion of the waste stream decreased total system costs to $90 per ton of waste collected.

CHAPTER 2 REFERENCES

1. Bishop, R., Willard Bishop Consulting, Ltd., personal communication, 1989.
2. **Ganotis**, C. G., and Hopper, R. E., "The Resource Recovery Industry," *Environmental Science and Technology,* **10(5):425-429,** May 1976.
3. **Glebs,** R.T., "Landfill Costs Continue To Rise," ***Waste*** *Age,* pp. 84-93, March 1988.
4. Government Advisory Associates, Inc., 1986-87 *Resource Recovery Yearbook (New* York, NY: 1987).
5. Institute For Local Self Reliance, *Garbage Disposal Economics: A Statistical Snapshot* (Washington, DC: 1987).
6. Institute For Local Self Reliance, *Costs of Recycling Programs* (Washington, D. C.: April 1989).
7. Johnson, B., "Portland: First In the West To Send Waste Long Distance, " ***World*** *Wastes 3* **1(10):21-26,** October **1988.**
8. Keller, J., "Curbside Recycling in RI Communities, " Presentation at Rutgers University, Nov. 17,1988, revised Dec. 27, 1988.
9. New York State Commission on Returnable Containers, *Final Report of the Temporary State Commission on Returnable Beverage Containers* (Albany, **NY**: Mar. 27, 1985).
10. Peters, A., and Grogen, P., "Community Recycling: What Is Working Best?" ***BioCycle*** **29(5):32-36,** May/June 1988.
11. **Pieters,** G. G. M., and **Verhallen,** T. M. M., "Participation in Source Separation Projects: Design Characteristics and Perceived Costs and Benefits, ' *Resources and Conservation* **12:95-1** *11, 1986.*
12. Rozett, J. M., "Resolving the "Bottle Bill" Controversy: The Role of Policy Analysis in Decision Making,' New *York Case Studies in Public Management,* no. 14, November 1984.
13. **Schall,** J., Energy Systems Research Group, Inc., personal communication, 1989,
14. Snow, D., and Johnson, C. A., "Trends in Collecting Recyclable," *Waste Alternatives-Recycling,* pp. 40-48, June 1988.

15. Snow, D. "Trends In Collecting Recyclable," *Waste Reduction and Recycling,* pp. 58-65, Summer 1989.
16. U.S. Department of Commerce, Bureau of the Census, *Government Finances in* 1985-86, Government Finances **GF-86**, No. 5 (Washington, DC: November 1987).
17. U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States, 1988*, 108th ed. (Washington, DC: U.S. Government Printing Office, December 1987).
18. U.S. Environmental Protection Agency, *Multimaterial Source Separation in Marblehead and Somerville, Massachusetts, SW-822* (Washington, DC: December 1979).
19. Waste-to-Energy **Report**, "Wall Street Sees Waste-To-Energy Market Likely To Grow Even In Recession, " *Wrote-To-Energy Report,* pp. 1-2, Jan. 27, 1988.
20. Waste-to-Energy Report, "Project Growth Seen Slowing, Operating Services Continuing to Expand," *Wrote-to-Energy Report,* pp. 1-2, Mar. 9, 1988.
21. Willard Bishop Consulting, Ltd., *Efficiency Guidelines For Curbside Recycling Programs* (Barrington, IL: February 1989).