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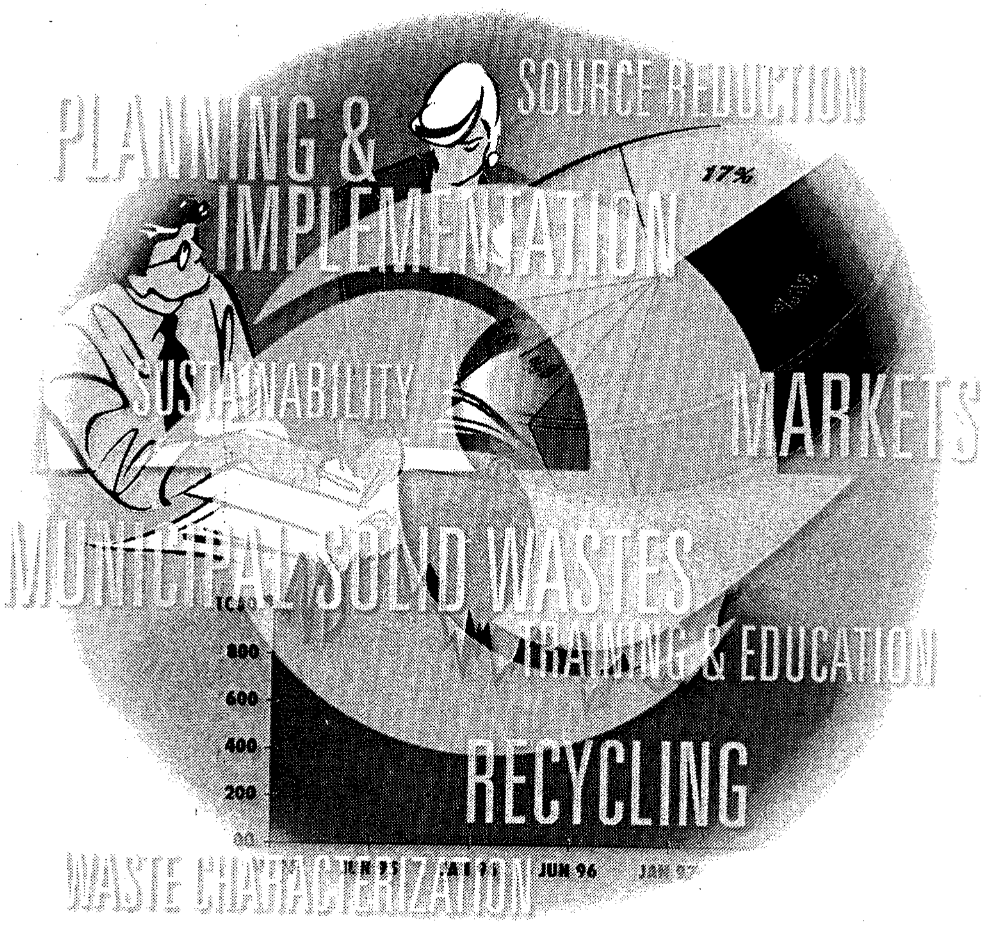
Solid Waste Management at the Crossroads



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SOLID WASTE MANAGEMENT AT THE CROSSROADS

by

FRANKLIN ASSOCIATES, LTD.

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PREFACE

As we approach the end of this century, it's appropriate to re-examine the status of municipal solid waste (MSW) management in the United States, and to chart a course for the twenty-first century. Solid waste management is only one of many issues faced by the nation. It's not the most dramatic issue, but solid waste is visible to everyone daily, and it involves how we use our resources as well as their end-of-life disposition. Thus, solid waste management has both practical and emotional aspects.

As observers and participants in the shaping of municipal solid waste management in the U.S. over nearly three decades, we have seen attitudes and actions go through many changes. We have placed these changes into "eras."

- ***Roots: Silent Spring to Earth Day 1970.*** The industrial expansion that came about in World War II, followed by the economic growth of the 1950s, brought prosperity to the United States, and along with it came air and water pollution, hazardous wastes poorly managed, population growth, and increased per capita consumption (and discards) of consumer goods.

  The infrastructure to deal with these discards was very different from that which we're accustomed to today. Prior to 1970, sanitary landfills were very rare. Wastes were literally "dumped," and often the organic materials in the dumps were burned to reduce volume. Waste incinerators with no pollution controls were also common in many cities; about 30 percent of MSW was incinerated in 1960. Recycling was mostly confined to the private sector, where decisions were made on the basis of economics, and organized composting programs were virtually nonexistent. Landfills (or dumps) received about 63 percent of MSW generated.

  In this era, Rachel Carson increased our environmental consciousness with her widely read book, ***Silent Spring.*** Environmental pollution, resource depletion, the "throwaway society," and packaging as a symbol of waste all began to be discussed and, eventually, acted upon. This era closed with the first Earth Day in 1970.

- ***The Age of Ferment: 1970 to 1976.*** By the decade of the 1970s, new regulations were leading to construction of sanitary landfills, and new federal air pollution regulations were shutting down the old incinerators. Recycling in the public sector was still at a very low level, although a base of commercial recycling continued and a few public programs were begun. The U.S. Environmental Protection Agency was established, and state and federal environmental programs were initiated. The federal Resource Conservation and Recovery Act of 1976 (RCRA) encouraged resource recovery, which was defined to include both waste-to-energy and materials recycling programs.

Inspired by the proliferation of single-serve throwaway packages, environmentalists continued to focus on packaging in the waste stream. Nonrefillable bottles and cans for soft drinks and beer were a particular target as they displaced refillable glass bottles. Beverage container deposit laws were enacted, first in Oregon, then in eight other states, and they were proposed at the national level. Litter reduction was a driving force in these measures, although conservation of materials and energy was also a motive.

The makers of aluminum cans responded by instituting recycling programs, with aluminum cans increasing from a negligible recycling rate in 1970 to 27 percent in 1975. Other containers and paper products were also recovered in the 1970s, usually through buy-back or drop-off sites (e.g., newspaper collection "drives.")

- ***The Era of Energy: 1977 to 1981.*** An oil embargo by Mid-Eastern producers brought the entire nation to attention in this period. Re-examination of our national energy policy took center stage. The government supported exploration of alternate energy sources, including energy recovery from combustion of MSW. While not many waste-to-energy plants were actually built in this period, the groundwork for their later construction was begun. Public emphasis on recycling increased somewhat, but progress was slow. Recovery for recycling of commercial and residential MSW did increase from 7.5 percent in 1970 to over 9 percent in 1980, but public composting activities were still negligible. About 82 percent of MSW generated was landfilled.

- ***The Quiet Years: 1981 to 1985.*** After the perceived energy crisis abated, federal and state efforts in solid waste management mostly focused on writing new landfill regulations. In 1985, combustion managed only about 7 percent of MSW, and recovery for recycling amounted to only 10 percent of residential and commercial MSW generation, leaving about 83 percent of the growing municipal solid waste stream to be landfilled. The stage was set for another era.

- ***Reawakening: 1986 to 1996.*** The latter half of the 1980s saw increased concerns raised about pollution in general, and there was a public and governmental perception that landfill shortages were imminent. This perception found a focus in the story of the "garbage barge," which left Long Island, New York in 1987 and had difficulty finding a place to unload the garbage. This story was widely "hyped" in the media. While there were some localized landfill shortages, a nationwide shortage never came to pass because new landfill capacity was built, driven both by economics and new landfill regulations.

There was renewed emphasis on recycling, and new public, as well as private, programs were instituted. In contrast to the recycling programs in the 1970s, curbside collection programs became common, offering both increased convenience and added costs. Public and private composting programs were added, and the combined recycling and composting rate rose to about 17 percent by 1990. Combustion also increased, with pollution controlled facilities replacing the old incinerators. The result was that MSW landfilled declined to 67 percent in 1990.

In the 1990s, while concerns about running out of landfill space have eased due to construction of many large permitted landfills, recycling and composting are still being emphasized on many levels in the U.S. National recovery levels reached 27 percent in 1995, and the percentage of MSW landfilled declined to about 57 percent of total MSW in 1995. Tonnage of MSW landfilled has also been dropping. Source reduction of the products we generate and discard is being taken seriously, and many source reduction programs are being implemented in public and private sectors of the nation. These source reduction programs are driven by both economic and environmental considerations.

- ***1997: Reality Check.*** As this century ends, many of the visionary dreams of the early 1970s have been realized: regulations to ensure safe landfilling and combustion of MSW have been written and are being enforced; a recycling and composting infrastructure has been built, with more to come, and source reduction, while difficult to measure, is being pursued. Nevertheless, the amount of municipal solid waste generated in the U.S. has continued to grow in most years (although the growth rate may be slowing). The growth is due to population increases, changes in demographics (e.g., fewer persons per household), and a growing economy. Strenuous efforts to recycle and compost materials have caused the amounts of MSW landfilled to slowly decline both in tonnage and as a percentage of the total generated.

  However, questions still remain. Can recycling and composting continue to grow at a rapid rate? How do our goals in the U.S. fit with the worldwide economy that affects our recycling efforts in ways not always foreseen in the past? Will our citizens be willing to pay to reach the ambitious recycling and diversion goals proposed in many states?

This report, while not the final word, is intended to provide some analysis and perspective on managing our municipal solid waste in the early years of the twenty-first century.

Bill and Marge Franklin — December 1997

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Executive Summary

In 1997, solid waste management in the United States is in a state of change, with the public sector seeking both improved cost effectiveness and increased diversion from landfill, and the private sector witnessing new companies emerging and existing companies downsizing and reorganizing. This state of change should lead to a reshaped and more efficient solid waste management infrastructure.

This report discusses the future of municipal solid waste management in the United States in a time frame extending to 2010. In this report, municipal solid waste (MSW) includes wastes generated from residences and commercial establishments. MSW generated can be managed by recovery for recycling and composting, combustion for energy recovery, or landfilling. Also, source reduction is becoming more prevalent as a means to reduce waste generated, thus reducing management costs.

The major findings of this report are summarized below.

Since 1991, the rate of growth of MSW generation has slowed.

Historically, generation of MSW in the United States has grown steadily, increasing from 88 million tons in 1960 to 208 million tons in 1995.* The trend has also been that MSW generation has grown more rapidly than population growth (Figure 1). Stated another way, generation of MSW per person has been increasing.

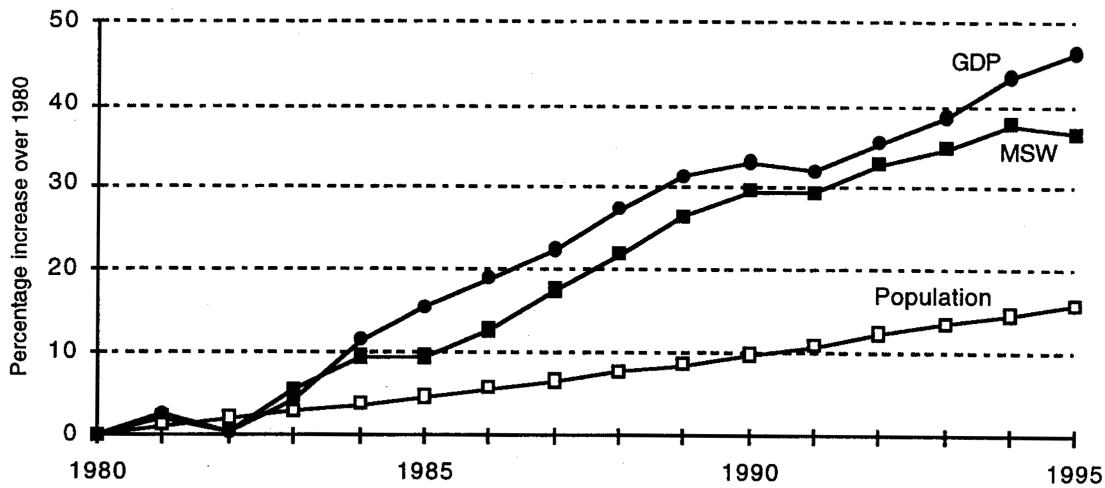
Economic growth (as measured by Gross Domestic Product, or GDP) has also stimulated MSW generation, although MSW has grown more slowly than GDP. Another important contributor to growth of MSW generation per person appears to be household size; as household size has decreased, MSW generation per person has increased.

Source reduction measures appear to be having an effect on MSW generation.

Starting about 1990, the relationship between MSW generation and GDP began to break down (Figure 1). Much of this can be attributed to diversion of yard trimmings away from the MSW management system by managing grass clippings and leaves at home. Other source reduction measures *may* be starting to take effect—generation of products other than yard trimmings and food wastes

* Data on historical MSW generation and management are from a U.S. Environmental Protection Agency publication, ***Characterization of Municipal Solid Waste in the United States: 1996 Update***. EPA 530-R-97-015. June 1997.

Figure 1. Growth of population, MSW generation, and GDP



also decreased between 1994 and 1995. On a per capita basis, generation of MSW was about the same in 1995 as in 1990.

In addition to the reduction in yard trimmings, source reduction measures are being practiced at businesses (e.g., double-sided copying, electronic data transfer). Manufacturers of durable and nondurable goods and packaging have instituted many source reduction measures (e.g., size reductions, lightweighting), which appear to be having an effect on the waste stream.

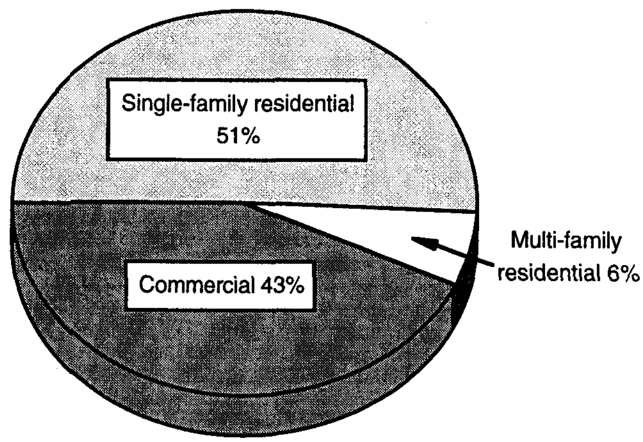
A conclusion of this report is that the growth rate of MSW generation will level off at about 1.3 percent per year, compared to increases of 3 to 5 percent annually in past decades.

Single-family residential MSW accounts for about half of total generation.

We estimate that single-family residential sources account for about 51 percent of all MSW. Multi-family residential MSW adds another 6 percent, and commercial MSW amounts to about 43 percent of total generation (Figure 2). While the composition of multi-family residential MSW is similar to that from single-family residences, the collection system is generally similar for commercial and multi-family MSW. To achieve high rates of recovery for recycling, both residential and commercial materials must be collected.

Recovery for recycling and composting will continue to increase at a rate faster than many have predicted, but slower than many others would prefer. We believe that 30 percent recovery in 2000 and 35 percent in 2010 is reasonable to expect, though not without effort and cost.

Figure 2. Sources of municipal solid waste, 1995



The real story in MSW management has been the large increase in recovery for recycling and composting, from about 10 percent in 1980 to 27 percent in 1995. We are projecting national average recovery rates of 30 percent in 2000 and 35 percent in 2010 as within reach. Although these projected recovery rates represent a declining rate of increase, considerable effort and expense will be required to achieve these levels of recovery.

Possible scenarios for achieving 30 percent recovery in 2000 and 35 percent recovery in 2010 are shown in Table 1. The total recovery rates for the materials in MSW are somewhat misleading (except for yard trimmings) because the materials categories each include many products that are not amenable to traditional recovery for recycling. For example, the paper and paperboard category includes tissue products, the aluminum category includes aluminum in furniture, and the glass category includes glass in furniture and appliances. In other words, the products that are amenable to recovery (e.g., containers) must be recovered at very high rates to achieve a higher overall recovery rate.

The 35 percent recovery rate could be achieved by increasing commercial collection to 40 percent of commercial generation, and single- and multi-family residential collection to 31 percent of residential generation. This would require increases in curbside collection, multi-family residential collection, drop-off and buy-back sites, and commercial collection. Processing facilities to meet the increased collection would also be required, as would markets for the collected materials.

Collection of materials from commercial sources is the key to success.

Achieving the rates of recovery projected for 2010 would be impossible without recovery from commercial sources (Figure 3). For our projected scenario,

Table 1

A SCENARIO TO REACH 30 PERCENT RECOVERY IN 2000 AND 35 PERCENT RECOVERY IN 2010

RECOVERY RATES BY MATERIAL

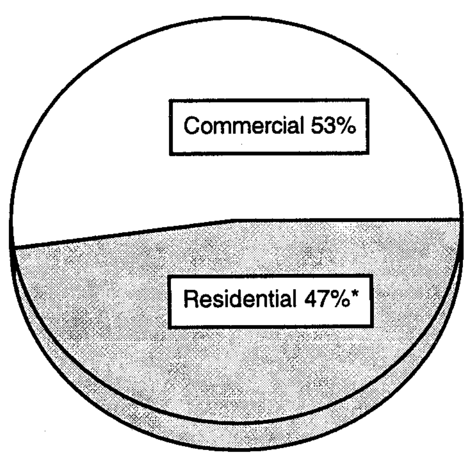
	1995	2000	2010
Paper and paperboard	40%	42%	47%
Glass	25%	26%	36%
Steel and iron	37%	40%	46%
Aluminum	35%	41%	43%
Plastics	5%	7%	10%
Wood	10%	11%	15%
Yard trimmings	30%	40%	50%
Food wastes	4%	6%	9%
Other materials*	15%	17%	19%
Total Municipal Solid Waste	27%	30%	35%

* Rubber and leather, textiles, miscellaneous.
These percentages represent possible scenarios to reach a goal. Many other combinations are possible.

Source: Franklin Associates, Ltd.

53 percent of total recovery would come from commercial sources, while 47 percent would come from residences.

Figure 3. Projected sources of MSW recovery, 2010



* Includes multi-family housing

Infrastructure development will continue on an incremental basis for collection vehicles, recyclable materials processing, transfer stations, and disposal via landfill and combustion. Mixed waste processing as a landfill diversion technique and other techniques to derive significant value from mixed waste are proving to be difficult to implement, and will not handle significant tonnage soon.

The direct involvement of both communities and private haulers in materials recovery activities has created a whole "new" infrastructure for collection and processing of recyclable materials, especially from residential sources. At the same time, recovery from commercial sources, e.g., office papers, has begun to flow more through MSW systems.

One bright area in infrastructure development is the forward integration of recyclables processing to create a higher value material output or to integrate processing with a user market. Also, improvements in composting techniques may come. Since much infrastructure is now in place, its useful life will be extended rather than replaced. Thus, new cycles of capital investment are not stimulating much investment in new technology. The decline in number of landfills coupled with increased landfill capacity stimulates demand for transfer stations. In fact, reported numbers of transfer stations exceeded numbers of landfills for the first time in 1996.

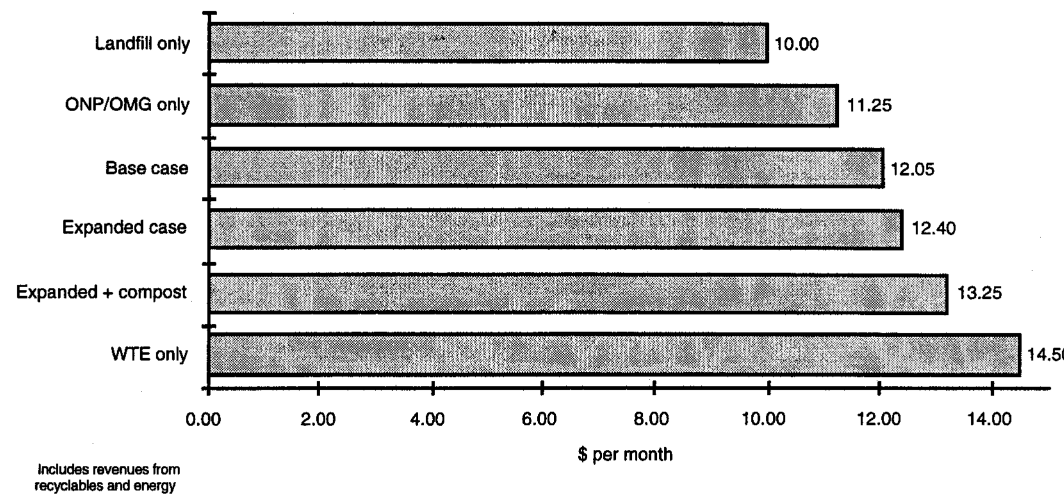
Markets will continue to be available for recovered materials, but there will always be discontinuities between supply and demand. Some of the available markets will not bring the high prices that collectors and processors would like to have. The worldwide economy will continue to be extremely important to most materials markets.

We believe that markets generally will be available for most recovered materials for the foreseeable future. There will, however, continue to be dislocations when supply and demand get out of balance due to normal business cycles, and prices will continue to fluctuate accordingly. All parties involved in recovering, processing, and using recovered materials must learn to adjust to these facts of life. The point is that truly recyclable materials that are recovered will "find a home" as long as contamination does not preclude their use (although there may be some regional problems finding markets). In times such as 1996 and 1997, when demand is down and prices for recovered materials are low, efforts to add more lower grade materials (e.g., mixed paper) will encounter problems.

Curbside collection of materials for recycling from single-family residences is a service that does come at a cost.

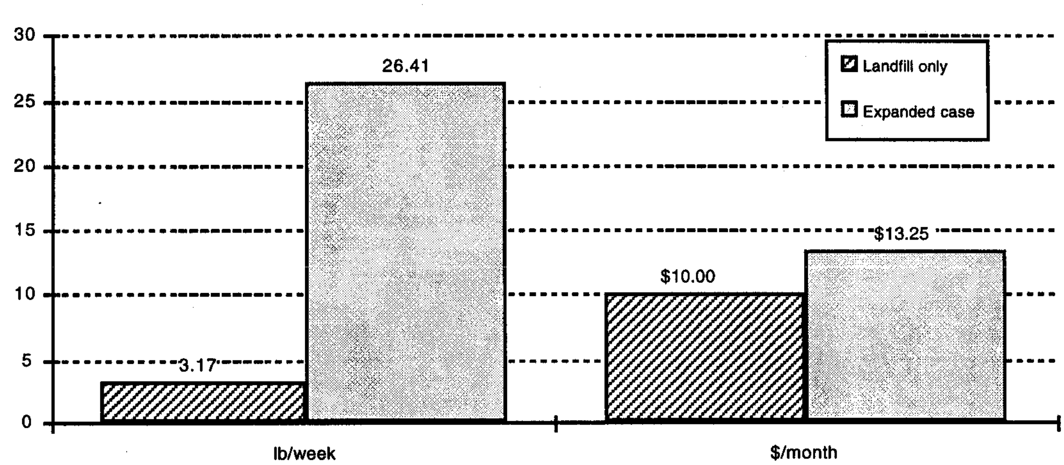
Revenues from residential curbside recycling programs usually do not cover program operating costs. However, thousands of communities have come to the decision that the relatively small cost increase provides a service that people are willing to support because they want to be involved in a program they perceive to be beneficial. Comparative monthly net costs (costs after revenues from sales of materials are deducted) are shown in Figure 4. (Note that these are average national costs; the relationships could vary, especially in regions with high landfill tipping fees.)

Figure 4. Monthly single-family household net costs for various MSW management scenarios



Viewed another way, the expanded case single-family curbside recycling scenario with recovery of yard trimmings costs about 33 percent more than the landfilling scenario (which includes a small amount of drop-off and buy-back recycling). The 33 percent increase in costs yields a *700 percent* increase in the amount of materials recovered (Figure 5). Thus, for a relatively small investment, a community can achieve a sizable diversion of materials from disposal.

Figure 5. Recovery (lb/week) and household cost ($/month) Landfill and expanded recycling and composting scenarios



Waste-to-energy will not increase much unless unforeseen events occur.

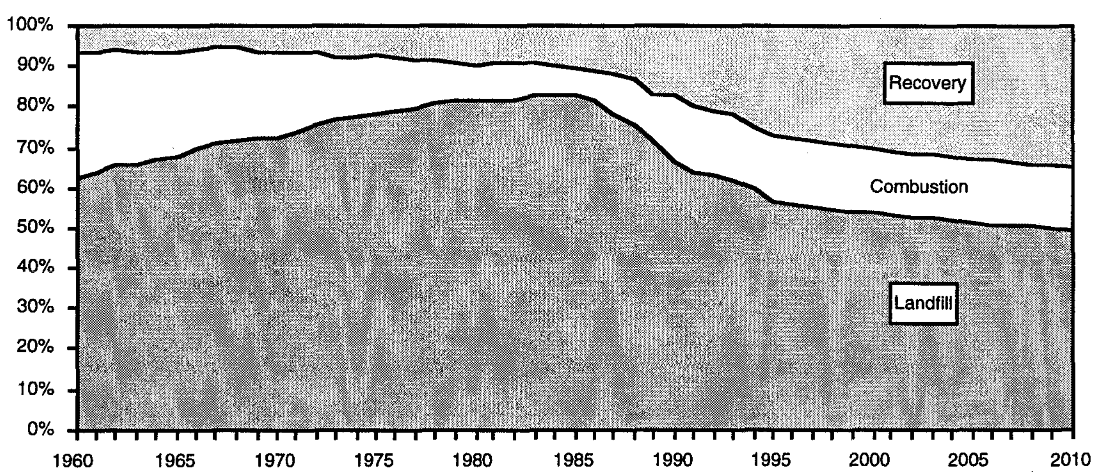
If current conditions remain unchanged, we are projecting tonnage of MSW combusted to be 36 million tons (16 percent of generation) in 2000 and 39 million tons (15 percent of generation) in 2010. For WTE to grow substantially, one or more of the following factors need to be in place:

- Tipping fees for WTE need to compare favorably with fees for landfilling. This can happen in areas of the country with high landfill costs.
- Revenues received for energy products need to increase by improving the efficiency of the waste-to-energy process.
- The local governmental units responsible for issuing permits must be convinced that WTE is a positive factor for the community. Both economic and environmental factors are important to communities.
- Legislative uncertainties need to be resolved.

Landfilling will continue to be an important part of municipal solid waste management, but tonnage landfilled will be "flat" or increase only slightly after 2000.

The percentage of MSW landfilled peaked at about 82 percent in 1987, and has been declining ever since; this decline is projected to continue through 2010 (Figure 6). At the same time, landfill capacity has increased. At 30 percent recovery and a modest increase in combustion, 54 percent of MSW (119 million tons) would be landfilled in 2000. At 35 percent recovery and another modest

Figure 6. Management of municipal solid waste, 1960 to 2010 (in % of total generation)



increase in combustion, 50 percent of MSW (126 million tons) would be landfilled in 2010. With capacity increasing and the amount of MSW available for landfill "flat," tipping fees are coming under pressure, and landfill revenues are declining in some areas.

Communities have many options for dealing with municipal solid waste. The goals of the community (and, in some instances, the state) determine the desired level of implementation of reduction, recycling, composting, combustion, and landfilling. Once goals are known, optimization of collection and processing systems can improve the economics of any system.

Communities have many reasons for choosing a combination of MSW management options (a concept known as integrated solid waste management). Usually decisions are based on multiple goals, e.g., public desire to recycle, industry's need for recovered materials, the need to preserve landfill space, and in some instances, state diversion mandates.

Management of solid wastes is a necessary service, and like all services, there is a cost attached. Our example analysis of typical management costs for single-family residential MSW shows that landfilling is the least costly alternative for most communities, with various scenarios of collection and processing of recyclable materials and yard trimmings to be more costly, and waste-to-energy to be the most costly on a dollars per ton basis (unless landfill costs are very high locally).

The least-cost alternative is, however, not necessarily the alternative chosen, whether the citizen or community is purchasing solid waste management or any other public service. While expectations vary from community to community, citizens generally demand some convenience and service from their governments or private providers, and generally they are willing to pay something extra for the service.

There are economies that can be achieved in providing solid waste management services, and we believe that these improvements will continue to be pursued. Some examples include modifying the frequency of household pickups of recyclable materials and refuse, instituting unit-based pricing for trash collection, improving processing systems, and source reduction measures such as encouraging more at-home management of yard trimmings.

There are real uncertainties about the level of recovery of materials in the decade after 2000 as diversion goals collide with marketplace realities.

The *national average* 35 percent recovery scenario for 2010 is developed on the basis of *what it takes* to reach that level of recovery. There are major hurdles to be overcome if the trend to increased recovery set in motion in the late 1980s is to prevail beyond 2000. Some material recovery rates must reach practical limits to achieve this level. Whether that will be achieved is dependent upon the priorities that states and local communities place on recovery and/or diversion.

The commercial sector will respond to economic forces above all else—generally on the basis of cost avoidance vs. conventional solid waste services. The driving forces are strongest for large quantities of material that have active markets. The recovery rates of these key components will be at or near their practical maximum by 2010. Not much can be expected to push total recovery of these key components higher.

The greatest challenge to continued growth of recovery of materials is from residential sources, because this sector of MSW management has entered a very challenging transition period.

- Cost effectiveness of curbside collection cannot be achieved based on revenue from recovered materials because collection costs drive the economics of curbside collection.

- The extensive curbside collection infrastructure already in place is based on the reality that this a service people are willing to pay for; the increased cost over conventional collection and disposal is relatively small. There is a benefit in satisfying citizens' desires to participate in an environmentally beneficial activity.

- Once in place, the infrastructure to collect, process, and prepare recyclable materials will likely stay, though it may expand and contract as markets fluctuate.

- To reach 35 percent recovery nationally, states with high recovery/diversion goals will have to offset those states with limited goals or no recovery goals.

- Private industry will continue to support recovery efforts for materials that can be recycled, but will not likely subsidize collection and processing of materials derived from residential curbside programs. Likewise, some states will likely reduce or eliminate funding that supports local recovery programs.

- The economics of increased recovery of materials is much more burdensome for programs that attempt to push to higher levels of recovery by adding materials or intensifying collection requirements.

- For those states and communities that wish to increase recovery or diversion beyond 35 percent on average, an added effort and refocus will be required. These efforts will include:

✓ Reaching practical recovery limits for some materials, e.g., corrugated boxes, newspapers, and yard trimmings.

✓ Increased recovery of commercial products such as high grade and mixed office papers.

✓ Curbside collection for nearly all single-family residences, recognizing that there is a small increased cost for this service and making the service as cost effective as possible.

✓ On-going educational programs aimed at keeping recovery rates up; these programs must be part of the recycling budget. This includes educating citizens about the environmental benefits of recycling.

✓ Encouraging market development for recovered materials, while recognizing that export markets are largely beyond local control.

✓ Adding materials and processes such as additional composting of organic materials, i.e., contaminated papers and food wastes.

Finally, local communities will be tested with the dual challenges of forcing costs down while responding to the recycled materials marketplace, which requires high quality recovered materials. Technology has not yet resolved this issue and may not until well into the next investment cycle, about 2005. With recovery for recycling and composting a background issue today, there will continue to be uncertain times in the long transition period.

Chapter 1

INTRODUCTION AND BACKGROUND

INTRODUCTION

The principal focus of this report is on the future of municipal solid waste (MSW) management, which includes recycling, composting, combustion, and landfilling. While source reduction has an important effect on generation of MSW, it occurs prior to the time when the materials enter the solid waste management system. Thus, source reduction is addressed only indirectly in this report.

To set the stage, an understanding of past and current trends is a necessary element of the analysis. This chapter provides an overview of recent (1995) municipal solid waste generation and a perspective on recent and historical waste management practices. Finally, this chapter introduces some of the issues to be addressed in this report.

TRENDS IN MUNICIPAL SOLID WASTE GENERATION*

Materials Included in this Report

Throughout this report, quantification of MSW is based on the series of characterization reports prepared by Franklin Associates, Ltd. for the U.S. Environmental Protection Agency (EPA). These reports are widely used throughout the United States. MSW as characterized in the EPA reports includes durable goods, nondurable goods, containers and packaging, food wastes, yard trimmings, and miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources. (Only products such as packaging and office wastes are included for industrial sources, i.e., industrial process wastes such as sludges are excluded.)

The EPA reports do *not* characterize other wastes that can be, and often are, managed along with MSW. These include nonhazardous industrial process wastes, municipal sludges, automobile shredder residue, and construction and demolition debris. To be consistent with the EPA characterization, this report also does not deal with these wastes, although they are an important portion of the total solid waste streams of population centers (rural and urban).

* Throughout this report, we have used the term municipal solid waste (MSW) in the commonly accepted sense—to refer to all the materials and products generated. Some recycling industry members have correctly pointed out that materials recovered for a useful purpose are not really waste. Until this semantics issue is resolved, we will continue to use the EPA terminology.

DEFINITION OF TERMS

The terminology used in this report is consistent with the U.S. EPA report, ***Characterization of Municipal Solid Waste in the United States: 1996 Update***. Definitions follow.

Generation refers to the weight of materials and products as they enter the waste management system from residential, commercial, and institutional sources. Generation is measured before any recovery for recycling, composting, or combustion takes place. Typically, generated material has been placed "at the curb" from a residential source or in a container from a commercial source. Thus, yard trimmings managed by being left on the lawn or composted in the back yard are not counted as "generated." Generation of some products, e.g., major appliances, is time lagged from the year of production, but most products are assumed to end their useful lives in the same year they are produced.

Recovery refers to materials removed from the waste stream for recycling or composting. The materials may be collected separately or they may be separated after collection. Recovery includes materials purchased for recycling and exports of recovered materials. Each major industry has its own techniques for reporting recovery (recycling) rates. EPA does not count industrial converting or fabrication scrap as recovery of MSW. When recovered materials are processed by an end user (e.g., a paper mill or glass plant), some residues are left. In the EPA reports, these residues are counted as part of recovery because they are removed from the municipal solid waste stream; the residues are assumed to be discarded as industrial wastes.)

Discards are the MSW remaining after recovery is subtracted from generation. Discards are assumed to be disposed through landfilling or combustion. In reality, a small portion of MSW is self-disposed at the point of generation (particularly in rural areas) or becomes litter. This amount is believed to be so small that it is counted as discards.

The EPA reports include only postconsumer products and materials, although some products (e.g., overissue newspapers that have been returned to the publisher unpurchased) are virtually indistinguishable from products defined as postconsumer by EPA. This issue is addressed later in this chapter.

Municipal Solid Waste Generation in 1995

Municipal solid waste generation and recovery in 1995 are shown in Table 1-1. This table is based on data from the latest EPA MSW characterization report (EPA 1997). Categories have, however, been rearranged to facilitate the analyses in later chapters.

Durable Goods. Durable goods include major appliances (often called white goods in the recycling industry), rubber tires, and automotive batteries. Durable goods also include furniture and furnishings, carpets and rugs, small appliances, and other miscellaneous durables. It should be noted that the EPA methodology has a built-in time lag between production of durable goods and their entry (generation) into the MSW stream.

Table 1-1

MUNICIPAL SOLID WASTE GENERATION, RECOVERY, AND DISCARDS, 1995
(in thousands of tons)

	Generation	Recovery	Recovery %	Discards
DURABLE GOODS				
Major appliances	3,420	2,070	61%	1,350
Steel and iron only*	2,600	2,070	80%	530
Rubber tires	3,770	660	18%	3,110
Automotive batteries	1,910	1,830	96%	80
All other	22,130	760	3%	21,370
Total Durables	31,230	5,320	17%	25,910
NONDURABLE GOODS				
Newspapers	13,130	6,960	53%	6,170
High grade office papers	6,800	3,010	44%	3,790
Magazines and catalogs (OMG)	4,370	1,000	23%	3,370
Other printing-writing papers	11,390	1,750	15%	9,640
Other papers	7,780	0	0%	7,780
Subtotal papers	43,470	12,720	29%	30,750
Textiles (clothing, linens)	4,890	790	16%	4,100
Plastics	5,080	10	0%	5,070
Other nondurables	3,600	0	0%	3,600
Total Nondurables	57,040	13,520	24%	43,520
CONTAINERS AND PACKAGING				
Cans, bottles, and jars				
Glass	11,530	3,140	27%	8,390
Steel	2,640	1,500	57%	1,140
Aluminum	1,620	990	61%	630
Plastics				
PET soft drink	660	300	45%	360
Other PET	330	40	12%	290
HDPE natural	630	190	30%	440
Other HDPE	700	120	17%	580
Other containers	220	0	0%	220
Subtotal plastics	2,540	650	26%	1,890
Subtotal cans, bottles, jars	18,330	6,280	34%	12,050
Corrugated boxes	28,800	18,480	64%	10,320
Folding cartons	5,820	1,070	18%	4,750
Bags and sacks				
Paper	1,990	340	17%	1,650
Plastic	1,170	40	3%	1,130
Wraps				
Paper	70	0	0%	70
Plastic	1,720	40	2%	1,680
Wood pallets and boxes	10,590	1,430	14%	9,160
Other packaging				
Steel (lids, strapping)	210	50	24%	160
Aluminum (foil, closures)	350	30	9%	320
Paperboard	260	0	0%	260
Paper	1,120	0	0%	1,120
Plastics	2,270	20	1%	2,250
Miscellaneous	160	0	0%	160
Total containers and packaging	72,860	27,780	38%	45,080
Total products and packaging	161,130	46,620	29%	114,510
Yard trimmings	29,750	9,000	30%	20,750
Food wastes	14,020	570	4%	13,450
Miscellaneous inorganic wastes	3,150	0	0%	3,150
TOTAL MSW	208,050	56,190	27%	151,860

* Note that steel and iron are recovered at a higher rate than total recovery for major appliances, because few other materials in the appliances are recovered.

Source: EPA, Characterization of Municipal Solid Waste in Municipal Solid Waste: 1996 Update (June 1997), and Franklin Associates, Ltd.

Nondurable Goods. The largest single component of nondurable goods is newspapers. Other paper products such as office papers, directories, magazines, books, other printed products, and tissue paper products are also included. This category includes plastic products such as trash bags,* clothing and other textiles, disposable diapers, and other miscellaneous nondurable products.

Containers and Packaging. This is a diverse component of MSW, including cans, bottles, and jars made of glass, steel, aluminum, and plastics, corrugated boxes, folding boxes (e.g., cereal boxes), paper and plastic wraps, paper and plastic bags and sacks, pallets and crates, and various other types of packaging. When the typical citizen thinks of recycling, packaging products (along with newspapers) most often come to mind.

Other MSW. The EPA characterization reports include an "Other Wastes" category that is made up of yard trimmings, food wastes, and other miscellaneous inorganics. Yard trimmings and food wastes are large components of the waste stream and are targeted by composting programs. Miscellaneous inorganics are not well defined, but include kitty litter, bits of broken crockery, dirt and stones, and the like.

Residential and Commercial Waste Streams

The distinction between residential and commercial sources of MSW is important because the nature of the two waste streams is quite different. Also, collection for disposal and collection for recovery are almost always carried out differently depending on the source. The split between residential and commercial wastes was developed internally at Franklin Associates by evaluating use patterns of each of the 46 categories of products and materials documented annually in the EPA MSW characterization report. For example, 85 percent of newspapers are estimated to be generated by residential sources, while 90 percent of corrugated boxes are estimated to be unpacked in commercial settings. There is no precise way to make this split, but our methodology has been reviewed by industry experts, and there is consensus that our total numbers for residential and commercial wastes are close to those actually experienced.

Residential MSW is further divided into single-family and multi-family sources. MSW disposed from single-family residences is most often collected by packer trucks at the curb or otherwise at the home. At multi-family residences (defined here as more than four units) and commercial sites, collection is most often from "dumpsters" or larger roll-off containers. (For this reason, commercial haulers often include MSW from multi-family residences with commercial waste.) The characteristics of wastes from multi-family residences are, however, more similar to those from single-family residences, with the

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* Plastic trash bags are classified as nondurable goods rather than packaging because they are not used to package or carry products.

Table 1-2

RESIDENTIAL AND COMMERCIAL SOURCES OF MSW, 1995
(in thousands of tons and percent)

	Durable Goods	Nondurable Goods	Containers & Packaging	Yard Trimmings	Food, Other	Total MSW
Residential						
Generation	18,740	35,360	28,950	26,780	8,590	118,420
Recovery	480	9,700	7,220	8,820	80	26,300
% Recovery	3%	27%	25%	33%	1%	22%
Commercial						
Generation	12,490	21,680	43,910	2,970	8,580	89,630
Recovery	4,840	3,830	20,560	180	490	29,900
% Recovery	39%	18%	47%	6%	6%	33%
Total MSW						
Generation	31,230	57,040	72,860	29,750	17,170	208,050
Recovery	5,320	13,530	27,780	9,000	570	56,200
% Recovery	17%	24%	38%	30%	3%	27%

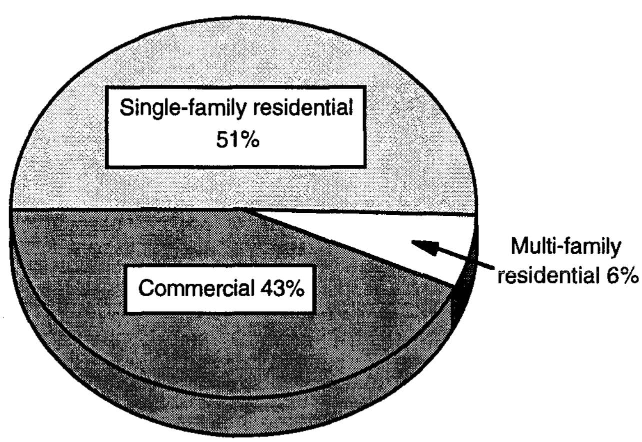
Residential includes both single-family and multi-family MSW.

Source: Franklin Associates, Ltd. (Appendix A).

exception of yard trimmings. An allocation of MSW generation and recovery to residential and commercial sources is shown above in Table 1-2.

As shown in Figure 1-1, MSW from single-family residences amounts to an estimated 51 percent of the total, multi-family residences contribute 6 percent

Figure 1-1. Sources of municipal solid waste, 1995



of the total, and commercial sources account for 43 percent of the total. Thus, nearly half of MSW generation comes from sources other than single-family residences.

Preconsumer and Postconsumer Materials

As described earlier, the basic data for this report come from a series of EPA MSW characterization reports. These reports include only postconsumer MSW materials as characterized by EPA. Converting and fabricating scrap (preconsumer materials) are not included.

As an illustration of how different definitions create different recovery rates, even though the same data series is used as a source, a comparison of the EPA methodology and paper industry calculations of recovery is shown in Table 1-3. Generation of paper and paperboard as calculated for EPA is lower than new

Table 1-3

COMPARISON OF PAPER INDUSTRY AND EPA RECOVERY CALCULATIONS, 1995
(In thousands of tons and percent)

	AF&PA Calculation	EPA Calculation
New Supply*	96,050	98,140
Preconsumer Recovery**		
Converting scrap		9,050
Overissue papers		860
Preconsumer Recovery		9,910
Diversion out of MSW***		8,350
Adjustment for imported corrugated boxes†		1,660
Generation of municipal solid waste††		81,540
Total Recovery‡	42,530	
% of New Supply	44.3%	
Postconsumer Recovery‡‡		32,620
% of Generation		40.0%

* American Forest & Paper Association. Production plus imports minus exports. AF&PA calculation includes an adjustment for product import/exports.
** Estimated by Franklin Associates, Ltd.
*** Paper products, e.g., construction paper, not classified as municipal solid waste.
† Boxes containing imported products. Estimated by Franklin Associates.
†† New supply minus preconsumer recovery minus diversion plus imported boxes.
‡ American Forest & Paper Association. Domestic mill consumption plus exports plus other uses.
‡‡ Total recovery minus preconsumer recovery.

supply of paper and paperboard as calculated by the American Forest & Paper Association (AF&PA). This is because for EPA, recovered converting scrap and overissue newspapers are deducted from generation. (Unrecovered converting scrap and overissue newspapers are counted as part of MSW generation.) Other paper and paperboard products (such as bathroom tissue that goes into the wastewater treatment system) are considered to be diverted out of the MSW stream. Also, an estimated tonnage for corrugated containers used to ship consumer products into the United States is added.

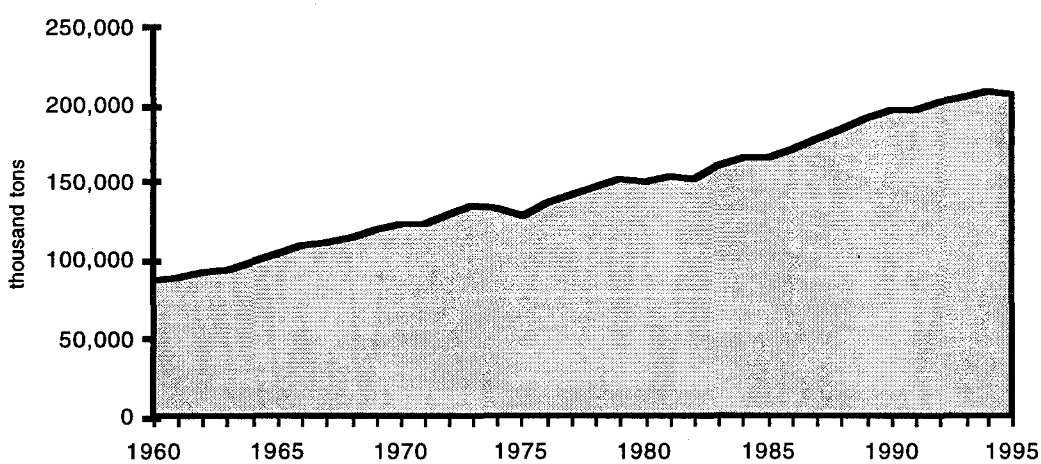
Total recovery as reported by the American Forest & Paper Association is higher than calculated postconsumer recovery as reported by EPA because recovered converting scrap and overissue newspapers are deducted for EPA. Also, AF&PA new supply data take account of imports and exports of converted products (such as envelopes and boxes) and thus are somewhat lower than the new supply data used for the EPA generation estimates. Overall, this means that the AF&PA calculated recovery rate will always be higher than the calculated EPA recovery rate, even though both are derived directly from AF&PA statistics. (Note that pre- and postconsumer values in the EPA column of Table 1-3 add up to the AF&PA total.)

While differences for other products and industries may not be as dramatic, the EPA methodology is applied as uniformly as possible—that is, every effort is made to exclude recovered preconsumer (converting/fabrication) scrap from both MSW generation and recovery.

Historical Perspective on MSW Generation

Total and Per Capita Generation. Generation of municipal solid waste has increased steadily over the 35-year period documented for EPA (Figure 1-2).

Figure 1-2. Historical generation of municipal solid waste



Historically, only in recession years has the actual tonnage of MSW *generated* declined. The decline from 1994 to 1995 is due to a small decline in containers and packaging (glass, steel, and aluminum containers) and an estimated 5 percent decline in yard trimmings. It remains to be seen whether this is a new long-term trend.

Part of the increase in MSW generation is, of course, due to increasing population. To eliminate the effects of population increase, MSW generation can be calculated on a pounds per person per day or per year basis (Table 1-4 and Figure 1-3). The table and figure show once again a steady increase in per capita

Table 1-4

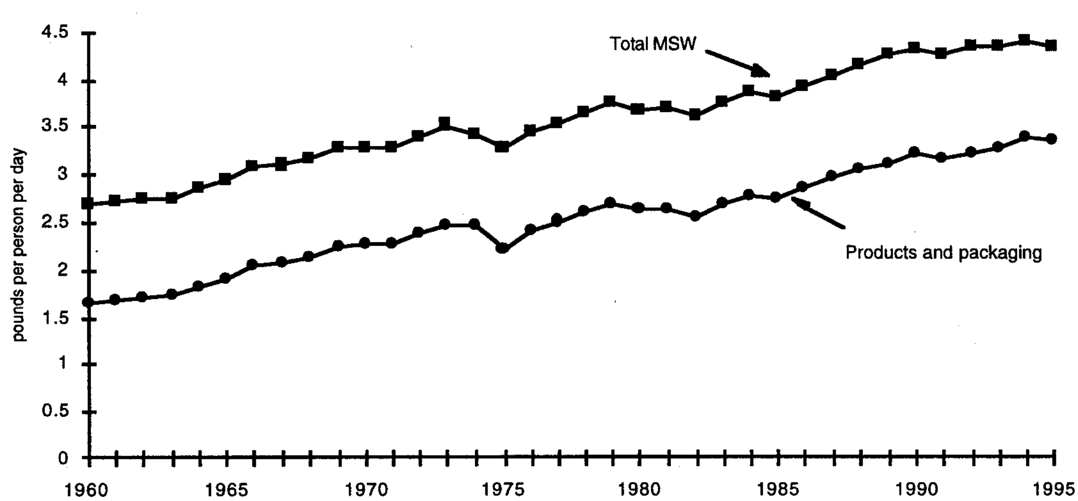
PER CAPITA GENERATION OF MSW, 1980 TO 1995
(in pounds per person per day)

	1980	1990	1995
Products and packaging	2.63	3.21	3.36
Yard trimmings, food wastes, other	1.03	1.12	0.98
Total MSW	3.66	4.33	4.34

Source: EPA. Characterization of Municipal Solid Waste: 1996 Update.

generation of MSW, except in recession years. However, per capita generation has "leveled off" since 1990. Per capita generation of products and packaging has continued to increase except in recession years, but estimated yard trimmings generation has declined since 1990, primarily due to increased efforts to keep yard trimmings out of the waste stream. (Yard trimmings are not counted as part of MSW generation unless they are collected for disposal or composting.)

Figure 1-3. Per capita generation of MSW, 1960 to 1995



Generation of Products and Materials. While overall generation of MSW has been increasing, the composition of products and materials has not been constant. This is important to MSW managers, as the nature of the products and materials affects decisions on recycling, composting, energy recovery, and disposal. Changes in composition of MSW by product category are shown in Table 1-5 and Figure 1-4.

Table 1-5

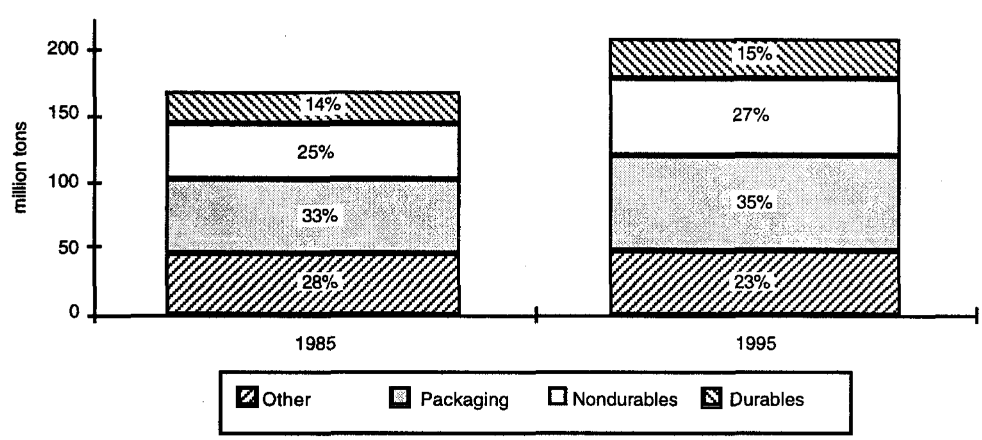
MSW GENERATION BY PRODUCT CATEGORY, 1970 TO 1995
(in thousands of tons and percent of total)

	1970		1980		1990		1995	
Category	**000 tons**	**Percent**	**000 tons**	**Percent**	**000 tons**	**Percent**	**000 tons**	**Percent**
Durable goods	14,660	12%	21,800	14%	29,810	15%	31,230	15%
Nondurable goods	25,060	21%	34,420	23%	52,170	26%	57,040	27%
Containers and packaging	43,560	36%	52,670	35%	64,220	33%	72,860	35%
Other materials	37,780	31%	42,750	28%	51,100	26%	46,920	23%
Total MSW	121,060	100%	151,640	100%	197,300	100%	208,050	100%

Source: U.S. EPA. Characterization of Municipal Solid Waste in the United States: 1996 Update.

Tonnage of durable goods generated increased over the years until the 1990s, when generation increases became rather "flat." The percentage of MSW made up of durable goods has remained fairly constant. By contrast, tonnage generation of nondurable goods has steadily increased, as has the percentage of nondurables in MSW. Most of the increase has been due to paper products—newspapers, office papers, and other printed products. (Newspaper generation, however, declined from 1994 to 1995.)

Figure 1-4. Generation of MSW by category



Containers and packaging make up the largest product category of MSW, with increasing tonnage over the years. Corrugated boxes and other paper packaging, glass bottles and jars, wood pallets, and plastic packaging account for most of the tonnage in this category. While the general trend in generation of containers and packaging has been up, the total generation declined by about one-half of one percent from 1994 to 1995. Generation of glass, steel, and aluminum containers all declined in that period.

Food wastes and yard trimmings are the most difficult components of MSW to quantify, and they represent substantial tonnage. It appears that actual tonnage of yard trimmings is declining due to programs in many states designed to keep these materials out of landfills; these programs include landfill bans and encouragement of backyard composting and leaving clippings on lawns (grasscycling).

The product categories in MSW by tonnage and by percent of total generation for the 10-year period 1985 and 1995 are displayed above in Figure 1-4. While tonnage increased in each category, the percentage that is nondurable goods increased by 2 percent of total MSW generated, and the percentage that is containers and packaging also increased by 2 percent of total MSW generated. The percentage that is "Other"—mostly yard trimmings and food wastes—decreased. (Note that as measures are taken to keep yard trimmings and food wastes out of the waste stream, the relative percentages of all categories would change even if tonnages of the other categories remained constant.)

Changes in the material composition of MSW over the years are shown in Table 1-6. Paper and paperboard products have dominated MSW generation as far back as estimates have been made. Yard trimmings are the second largest materials category, although the tonnage and percentage of yard trimmings have

Table 1-6

MSW GENERATION BY MATERIAL CATEGORY, 1970 TO 1995
(in thousands of tons and percent of total)

	1970		1980		1990		1995	
Category	**000 tons**	**Percent**	**000 tons**	**Percent**	**000 tons**	**Percent**	**000 tons**	**Percent**
Paper	44,310	37%	55,160	36%	72,720	37%	81,540	39%
Yard trimmings	23,200	19%	27,500	18%	35,000	18%	29,750	14%
Plastics	3,720	3%	6,830	5%	17,130	9%	18,990	9%
Metals	13,830	11%	15,510	10%	16,550	8%	15,850	8%
Food wastes	12,800	11%	13,000	9%	13,200	7%	14,020	7%
Wood	3,720	3%	7,010	5%	11,900	6%	14,860	7%
Glass	12,740	11%	15,130	10%	13,110	7%	12,830	6%
Other materials	6,740	6%	11,500	8%	17,690	9%	20,210	10%
Total MSW	121,060	100%	151,640	100%	197,300	100%	208,050	100%

Source: U.S. EPA. Characterization of Municipal Solid Waste in the United States: 1996 Update.

been declining as more programs to divert yard trimmings from landfills have been implemented. The remainder of MSW in 1995 was fairly evenly distributed (e.g., 6 to 9 percent by weight of total MSW) among plastics, metals, food wastes, wood, glass, and all other products, such as textiles, rubber, and leather.

Generation of plastics in MSW has grown rapidly, both in tonnage and in percentage of total. Metals, glass, and food wastes have declined in percentage of the total waste stream. Wood, on the other hand, has increased in tonnage and percentage of MSW.

Factors Driving Changes in MSW Generation

While the factors driving changes in quantities and composition of municipal solid waste are not fully understood, many factors have been identified (Franklin 1992). Some factors that tend to increase MSW generation are discussed below. Undoubtedly there are more factors that have not been documented.

- Population growth is the most obvious factor contributing to growth in MSW generation. If per capita generation of MSW stayed constant, total quantities would grow proportionately to population growth. The fact is, however, that MSW generation has increased faster than population (Figure 1-5). Said another way, per capita generation of MSW has increased over the years.

- There is a high degree of correlation between MSW generation and economic activity as measured by Gross Domestic Product (Figure 1-6). This is reasonable because more economic activity means more goods

Figure 1-5. U.S. population and MSW generation, 1960 to 1995

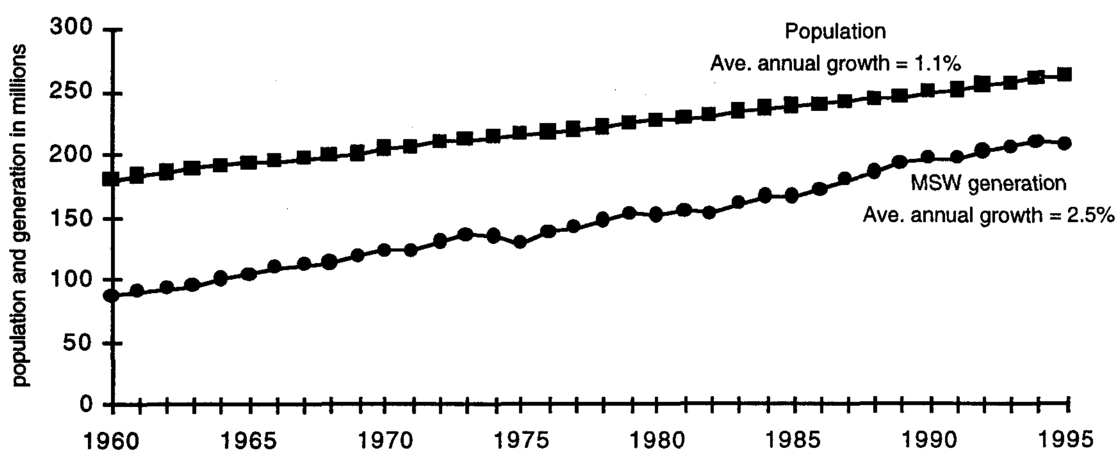
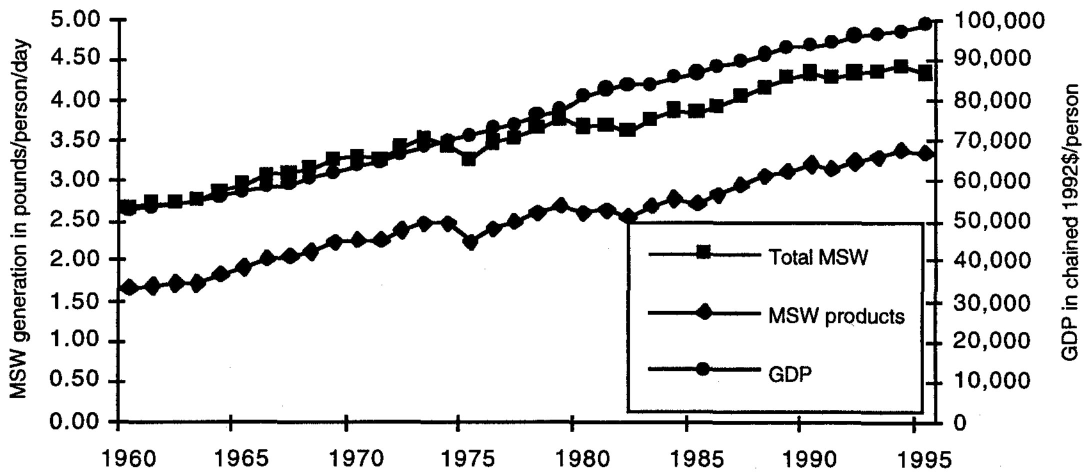


Figure 1-6. MSW generation and Gross Domestic Product



sold and more packaging for the goods. For 35 years, 1960–1995, the correlation coefficient (r) = 0.980. If we correlate a more recent time frame, 1980–1995, (r) = 0.968. As more and more yard trimmings are kept out of the waste stream, the correlation with total MSW is weakened.

For the same period, correlation of products only (no yard trimmings, food wastes, or miscellaneous inorganics) yields (r) = 0.980, a higher degree of correlation.

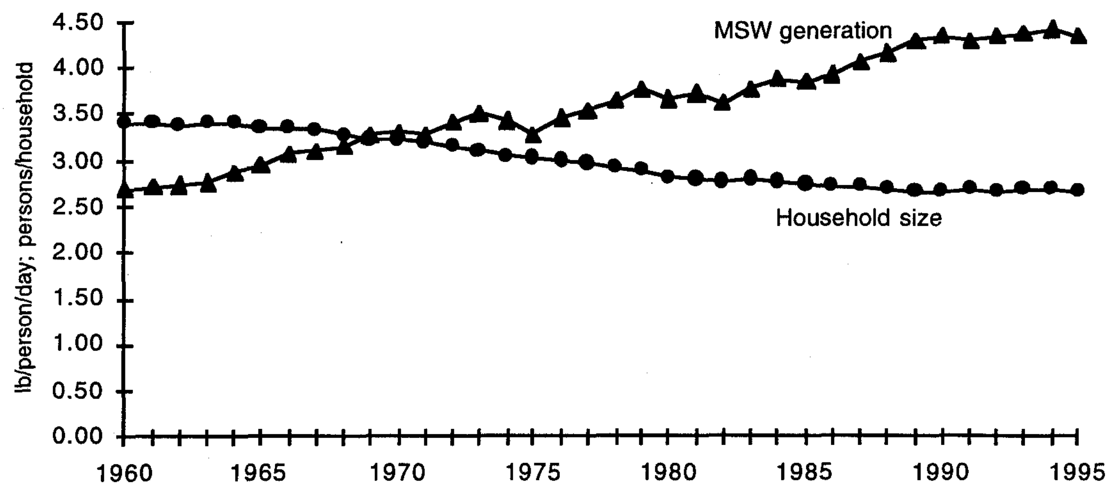
For these correlations, MSW generation is stated in pounds per person per day, while GDP is stated in chained 1992 dollars* per person. This is done to eliminate the growth in MSW due solely to population increases.

- There appears to be an inverse correlation between household size and MSW generation (Figure 1-7), and the number of one-person households has been increasing faster than population (Franklin 1992, EPA 1994). Growth of population and growth in number of households are contrasted in Figure 1-8. Since 1980, the percentage increase in number of households has been much greater than increase in population.

Per capita generation tends to be higher in smaller households. Small households will have much the same basic equipment (e.g., appliances,

* In 1996, the Bureau of Economic Analysis replaced the old fixed-weighted (1987 dollars) index with an improved indexing system that includes "chained" (multiplied) annual changes (Commerce 1996).

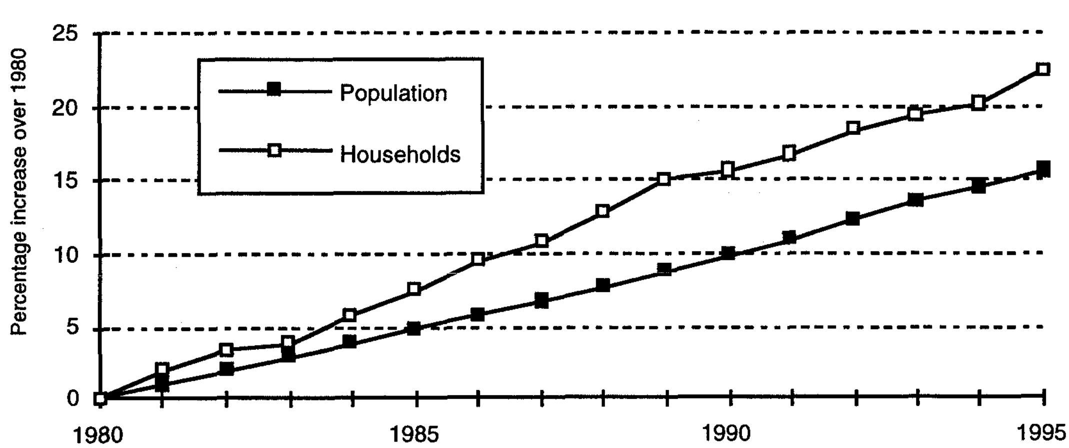
Figure 1-7. U.S. MSW generation and household size



furniture) as larger households. A one or two-person household will subscribe to the same newspaper as a larger household. Also, there may be less economy of scale in purchases of food and household supplies for a small household.

- As numbers of dual-income families and families headed by a single parent have increased, there have been other life-style changes. A Yale University paper (Godbey 1996) points out that, while data are hard to find, time scarcity and the *perception* of time scarcity can result in behavior that increases waste generation. The fast pace of modern life,

Figure 1-8. Growth of population and households



many conflicting activities, and longer work hours for some people, as well as families with working mothers, are among the reasons cited for increased waste generation.

For example, these households may tend to use more prepared foods and other labor-saving products (e.g., small appliances, disposable paper napkins and diapers), which may increase packaging and other discards. Also, more automobiles may be needed by these families for transportation to work.

- Increasing consumption of fresh fruits and vegetables, poultry, fish, and cheese has meant that more corrugated and plastic containers are used to transport products. Also, the corrugated containers are often transported on wood pallets.

- In offices, personal computers, high-speed copiers, and facsimile machines have added to paper used and discarded.

While the trend of MSW generation has been upward, both in total and on a per capita basis, other factors have worked toward reducing MSW generation. These include:

- New technologies and redesigns have permitted materials substitutions that have made many products and packages lighter. Flexible packaging (plastics, paper and, foil) has been substituted for rigid packaging (boxes, cans). Plastic containers have been substituted for glass containers. Many durable goods have been made lighter, mostly through increased use of plastics.

- Many products and packages that continue to be made of the same material have been lightweighted. Examples include steel and aluminum cans, glass and plastic bottles, and plastic bags, all of which use less material to accomplish the same purpose now as compared to a few years ago.

- The "electronic office" and other electronic communications, such as the exploding growth of the Internet, may reverse the trend toward more and more use of printing-writing papers.

- As noted earlier, reduction of yard trimmings entering the waste stream has been dramatic. This has been accomplished through landfill bans and encouraging residents to leave grass clippings on the yard and to practice backyard composting.

Average annual growth rates for MSW generation and several demographic and economic factors are shown in Table 1-7. The periods shown

Table 1-7

GROWTH RATES FOR MSW GENERATION AND OTHER FACTORS
(Average annual growth rates in percent)

	MSW Generation	Product Generation	Resident Population	GDP 1992$	No. of Households	Persons per Household
1960 – 1995	2.5%	3.2%	1.1%	3.2%	1.8%	-0.7%
1980 – 1995	2.0%	2.6%	1.1%	2.6%	1.7%	-0.6%
1990 – 1995	1.6%	2.8%	1.3%	1.9%	1.3%	0.0%

Source: EPA, Characterization of Municipal Solid Waste: 1996 Update; U.S. Bureau of the Census; Franklin Associates, Ltd.

are 1960–1995, 1980–1995, and 1990–1995. Over the entire 35-year period, MSW generation has grown an average of 2.5 percent annually. The average rate of growth was slower, however, from 1980 to 1995, and yet slower from 1990 to 1995 (1.6 percent average growth per year). If we look just at growth rate for products* in MSW, the 35-year average annual growth rate was 3.2 percent. For the more recent periods, it was 2.6 to 2.8 percent per year.

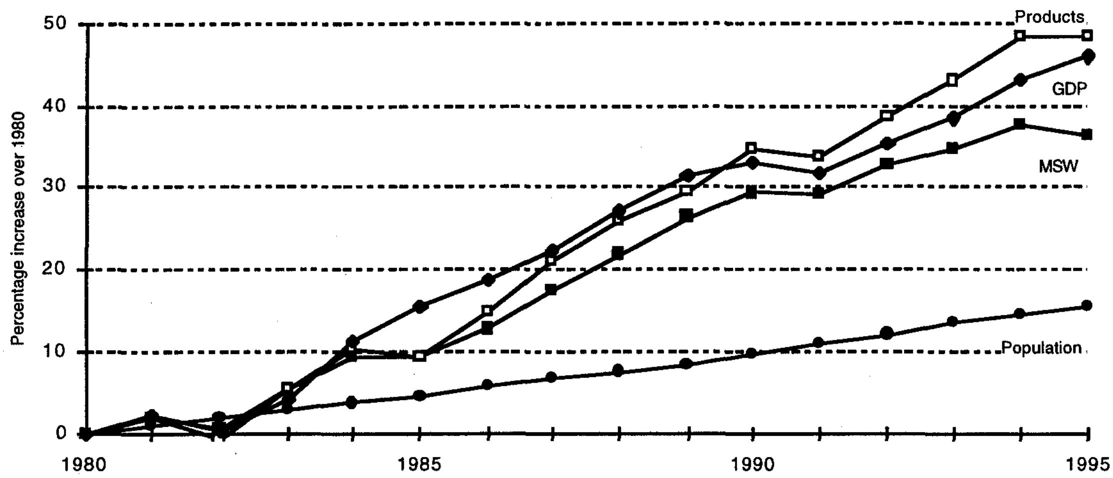
Average population growth was not much above one percent during the entire period. GDP annual growth was over 3 percent for the entire period, but slower in more recent years. Growth in number of households was higher than population growth over the entire 35-year period, although the rate of growth has slowed. Finally, household size declined, although there was virtually no change in the past five years.

To summarize, generation of municipal solid waste has been growing more rapidly than population or number of households, but less rapidly than the economy. The decline in numbers of persons per household contributes to growth in MSW generation for reasons outlined above. Figure 1-9 illustrates the trends in MSW generation, population growth, and GDP for the 15-year period 1980 to 1995.

The apparent decline in MSW generation between 1994 and 1995 is difficult to interpret. More data will be needed before any clear trend can be established. It is likely that source reduction activities other than diversion of yard trimmings are beginning to show results. Such source reduction activities include lightweighting of existing products, substitution of lighter materials to serve the same purpose, and changing patterns of use of electronic media affecting office paper demand.

* "Products" include manufactured products and exclude food wastes, yard trimmings, and some miscellaneous inorganic wastes (such as dirt and stones).

Figure 1-9. Growth of population, MSW generation, MSW product generation, and GDP



TRENDS IN MUNICIPAL SOLID WASTE MANAGEMENT

Once municipal solid waste is generated, several alternatives are available to public and private sector waste managers. Practices in the recent past are illustrated in Figure 1-10. In 1995, 208 million tons of MSW were generated. Forty-six million tons were recovered for recycling and 10 million tons were recovered for composting; thus, 27 percent of MSW was recovered for these purposes. The remainder—152 million tons—went to combustion facilities (33 million tons, or 16 percent) or landfill (118 million tons, or 57 percent).*

Trends in Historical MSW Management

There have been substantial changes in the ways in which MSW is managed in the United States (Table 1-8 and Figure 1-11). Recovery for recycling went from only 7 percent in 1970 to 15 percent in 1990 to 22 percent in 1995. Recovery for composting was almost nonexistent in 1970, but increased to 5 percent of generation by 1995 (making a total of 27 percent of MSW recovered in 1995). Combustion of MSW was 21 percent of generation in 1970 (mostly incineration without energy recovery), decreasing to 9 percent in 1980, then increasing to 16 percent in 1995.

Fluctuations in levels of recycling, composting, and combustion over the years have caused landfilling to vary from 73 percent of total MSW in 1970 to 81 percent in 1980, then decreasing to 57 percent in 1995. About 13 million fewer

* Residues from combustion facilities are not counted as municipal solid waste in the EPA MSW characterization reports.

Figure 1-10. Management of Municipal Solid Waste in 1995

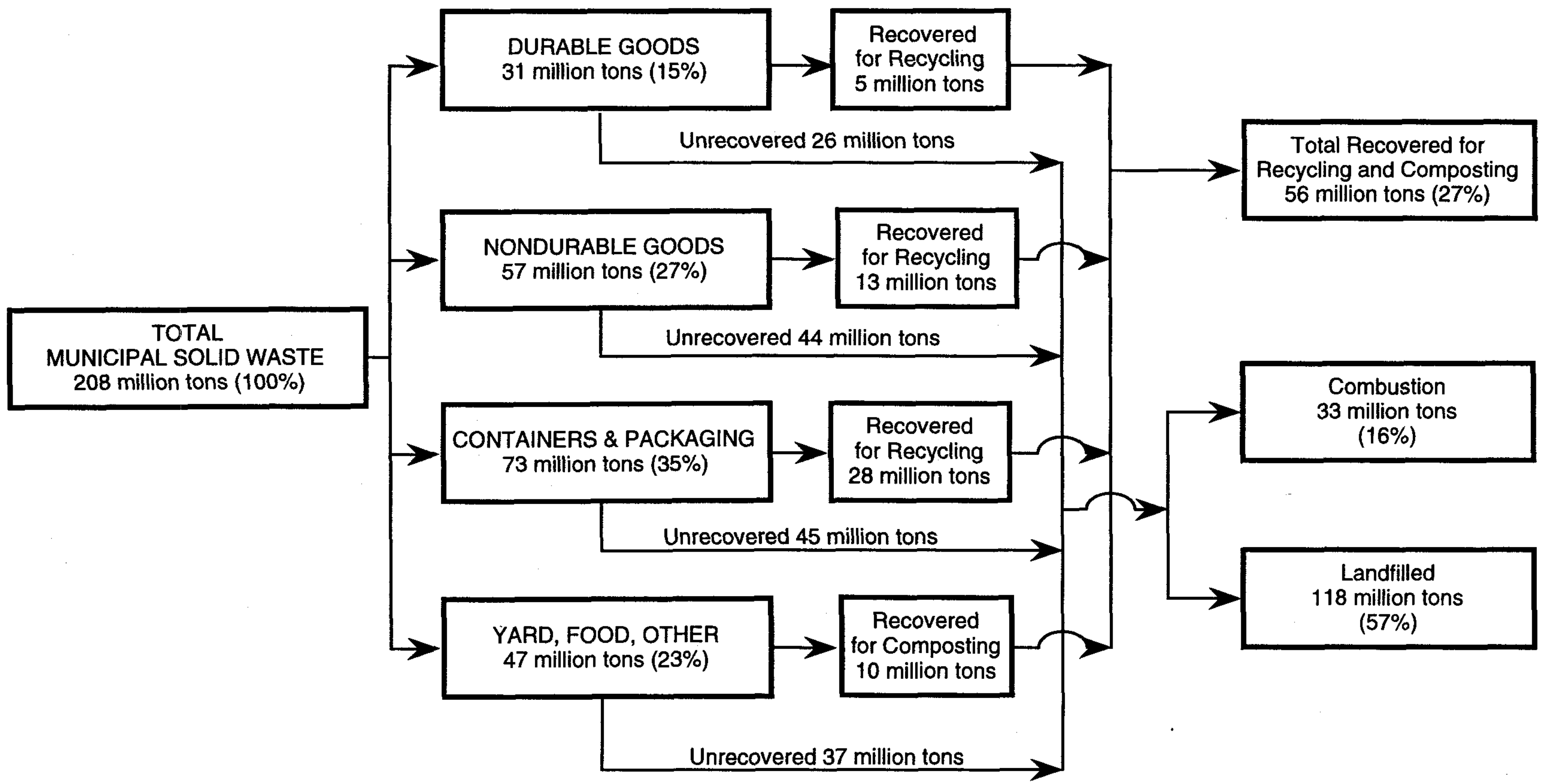


Table 1-8

MANAGEMENT OF MUNICIPAL SOLID WASTE, 1970 TO 1995
(in thousands of tons and percent of total)

	1970		1980		1990		1995	
	000 tons	Percent	000 tons	Percent	000 tons	Percent	000 tons	Percent
Recovery for recycling	8,020	7%	14,520	10%	29,650	15%	46,620	22%
Recovery for composting	0	0%	0	0%	4,200	2%	9,570	5%
Total materials recovery	8,020	7%	14,520	10%	33,850	17%	56,190	27%
Combustion	25,100	21%	13,700	9%	31,900	16%	33,470	16%
Landfill, other*	87,940	73%	123,420	81%	131,550	67%	118,390	57%
Total MSW	121,060	100%	151,640	100%	197,300	100%	208,050	100%

* Some MSW is littered or self-disposed (e.g., in rural areas), but these quantities are not documented.

Source: U.S. EPA. Characterization of Municipal Solid Waste in the United States: 1996 Update.

tons of MSW were landfilled in 1995 than in 1990, in spite of increased generation of MSW.

Trends in Recovery for Recycling and Composting

Recovery of MSW for recycling and composting remained at relatively low levels until the late 1980s, when there was renewed interest in solid waste management in the United States (Figure 1-12). Total recovered tonnage tripled from 1985 to 1995, while recovery percentage went up more than two and one-half times. This rapid increase in recycling and composting coincided with significant investment in collection and processing infrastructure, which probably will not be sustained at the same rate of increase. (See Chapter 5 for a discussion of projected recycling and composting.)

Figure 1-11. Management of municipal solid waste, 1960 to 1995

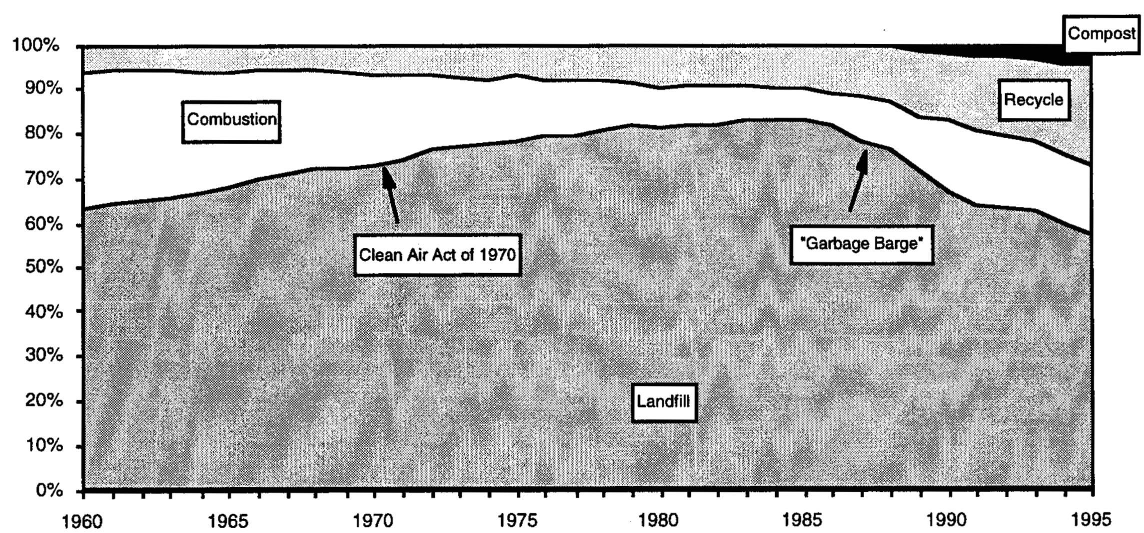
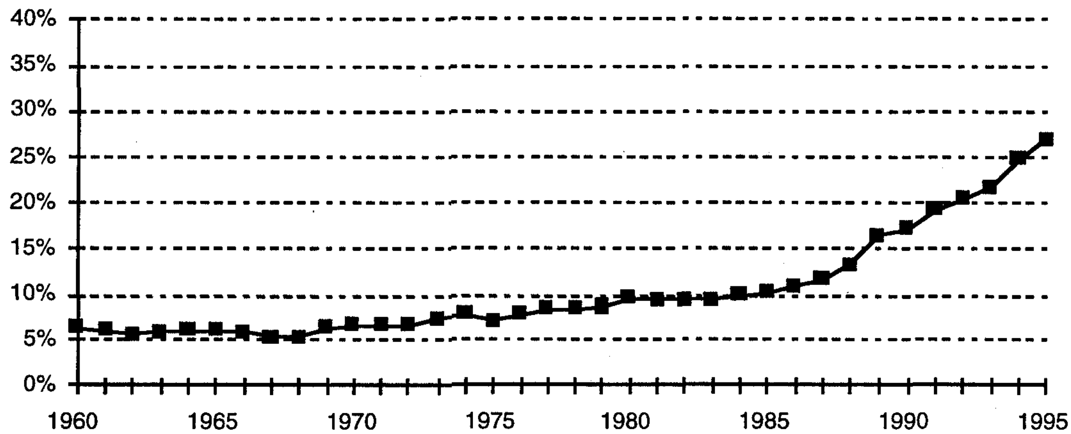


Figure 1-12. Recovery of MSW for recycling and composting (% of generation)



As Table 1-9 shows, paper and paperboard have dominated MSW recovery in terms of tonnage for the past quarter century. Generation of paper grew at therate of 2.3 percent per year between 1990 and 1995; however, recovery grew at 10 percent per year, or four times as fast, in the same time period.

While large-scale recovery of yard trimmings for composting did not develop until late in the 1980s, yard trimmings now represent the second largest recovered material in tonnage. Steel, glass, wood, aluminum, and plastics are also important contributors to recovery, and generally recovery of these materials, like paper, has grown faster than generation. Thus, there have been

Table 1-9

RECOVERY OF MUNICIPAL SOLID WASTE BY MATERIAL, 1970 TO 1995
(in thousands of tons and percent of generation, by material)

	1970		1980		1990		1995	
	000 tons	Percent	000 tons	Percent	000 tons	Percent	000 tons	Percent
Paper and paperboard	6,770	15%	11,740	21%	20,230	28%	32,620	40%
Yard trimmings	0	0%	0	0%	4,200	12%	9,000	30%
Steel	150	1%	370	3%	2,580	20%	4,230	37%
Glass	160	1%	750	5%	2,620	20%	3,140	25%
Wood	0	0%	0	0%	390	3%	1,430	10%
Aluminum	10	1%	310	18%	1,010	36%	1,020	35%
Plastics	0	0%	20	0%	370	2%	1,000	5%
All other *	930	12%	1,330	9%	2,450	7%	3,750	7%
Total Recovery (000 tons) and % of generation	8,020	7%	14,520	10%	33,850	17%	56,190	27%

* Other nonferrous metals (lead), rubber, textiles, food wastes.

Source: U.S. EPA. Characterization of Municipal Solid Waste in the United States: 1996 Update.

remarkable changes in the ways in which MSW has been managed in a five-year period.

While the information on recovery of materials is interesting, it is not very helpful in designing programs to manage municipal solid waste. Specifically, programs to recover materials are almost always focused on individual products (e.g., newspapers, cans and bottles), and the source of the products (e.g., residential or commercial). Products with recovery rates higher than 20 percent of generation in 1995 are highlighted in Table 1-10. This table illustrates some important points:

- Well over half of MSW tonnage recovered in 1995 (61 percent) came from corrugated boxes, newspapers, and yard trimmings.

- A high recovery *rate* for a specific product does not necessarily translate to a high tonnage recovered. Thus aluminum beverage cans had a 63 percent recovery rate in 1995, but contributed only about 2 percent of total materials recovered. Lead-acid batteries, at 96 percent recovery, represented only 3 percent of total recovery.

Table 1-10

RECOVERY OF PRODUCTS IN MUNICIPAL SOLID WASTE, 1995
(in thousand tons and percent)

	Recovery			Percent of	Percent of
Product	**Residential**	**Commercial**	**000 tons**	**Product Generation**	**Total Recovery**
Corrugated boxes	600	17,880	18,480	64%	33%
Yard trimmings	8,800	200	9,000	30%	16%
Newspapers	6,600	360	6,960	53%	12%
Glass bottles and jars	2,900	240	3,140	27%	6%
High-grade office papers	200	2,810	3,010	44%	5%
Major appliances	0	2,070	2,070	61%	4%
Lead-acid batteries	50	1,780	1,830	96%	3%
Steel packaging	1,400	150	1,550	54%	3%
Aluminum beverage cans	890	100	990	63%	2%
Magazines	540	130	670	28%	1%
PET soft drink bottles	270	30	300	46%	1%
HDPE milk & water bottles	170	20	190	30%	<1%
All other products	3,980	4,020	8,000	8%	14%
Total recovery	26,400	29,790	56,190	27%	100%
% of total recovery	47%	53%			

Source: EPA. Characterization of Municipal Solid Waste in the United States: 1996 Update. Allocations to residential/commercial recovery are by Franklin Associates and should be considered approximate.

Residential and Commercial Sources for Recovery of Materials

The infrastructures for collection of products vary greatly depending upon whether they are collected from residential or commercial sources. From residences, yard trimmings, newspapers and other mixed papers, and glass, steel, and aluminum containers are most commonly collected, typically through curbside collection or drop-off collection centers.

The commercial collection infrastructure is quite different. Corrugated boxes, which amount to by far the largest tonnage of products collected, are generally collected at the point of generation, e.g., stores and factories. Office papers are generally collected from office buildings. Major appliances and lead-acid automotive batteries, which are the other most commonly collected products, usually are collected through the retail outlets that sell new products.

Estimates of the sources of recovered products in 1995 are shown in Table 1-10. About 47 percent of all materials collected came from residential sources, while 53 percent came from commercial sources. While these numbers are approximate and vary from location to location, they have been extensively reviewed and provide a good rule of thumb.

Forces Driving Recovery Decisions

There are many forces driving decisions on recycling and composting—and some of these forces are in conflict with one another. Public sector and private sector decisions are often made using quite different criteria. Some of these decision drivers are discussed in this section.

Goals and Mandates. A number of states—e.g., California, Florida, Iowa, Minnesota, New Jersey, New York, North Carolina, Oregon, Washington, and Wisconsin—have recycling and/or reduction goals of 50 percent, usually by the year 2000. In some of these states, the goals are mandatory (Raymond 1996). Communities in these states are thus under pressure to meet the goals. In a few instances, mandates are extended to the commercial waste sector. (Examples include Minnesota, where communities can require businesses to recycle; Maine, where businesses must segregate white paper and OCC; and New Jersey, where most towns require businesses to recycle (Raymond 1996).) There is considerable discussion about the wisdom of removing or relaxing the mandates, but it's too soon (in 1997) to predict the outcome.

Economics. Costs are always a concern in both the public and private sectors. In "tight" economic times, when federal and state grants are cut back and private companies are downsizing and economizing, costs are a very important driver. Revenues from sales of recovered materials can offset costs, but recent volatility in revenues and long periods of relatively low prices for many recovered materials have aroused new concerns. In the private sector, e.g., offices and retail establishments, decisions on recycling will usually be based on the "bottom line," although other factors, including government requirements, may be considered. The bottom line "equation" for private establishments includes not only revenue received from sale of recyclable materials, but principally avoided disposal costs.

In the public sector, costs are definitely a concern to communities, although many communities have difficulty identifying specific costs for recycling (or, for that matter, for solid waste management). Capital investment can be significant if the community is responsible for providing the collection and processing equipment. Other public policy and/or political considerations may, however, be more important. These could include preserving landfill life or meeting the demands of citizens for convenient pickup service for recyclable materials. There do appear to be significant reductions in state spending, e.g., in Florida and Michigan, thus pushing the economic burden partly to the local level.

Siting Issues. The argument is often made that there is plenty of room for landfills in the United States. This is true in most, but not all, parts of the country. It is, however, very difficult to site any type of waste management facility, particularly landfills and combustion facilities (which are usually in or near metropolitan areas). Thus, community leaders may choose to encourage recycling and composting as a politically expedient way to defer the necessity for a new landfill, or to show a good faith effort toward waste reduction even though a community will need a new landfill anyway.

Citizen Demand. Many communities have instituted curbside collection of recyclable materials in direct response to citizen demands. Most people want to recycle, and curbside collection makes it convenient, although it does increase the total cost of solid waste management for residential MSW.

Energy/Environmental Issues. Careful life cycle analyses of energy use and environmental emissions have demonstrated that in almost every instance, recycling and yard trimmings composting save energy and reduce emissions (Franklin 1994). In the case of manufactured products, most of the savings come from the use of recovered materials in place of virgin materials because the recycling step enters the manufacturing sequence closer to the end product than removing and refining raw materials from the earth.

Energy conservation is becoming an important issue in solid waste because international programs and agreements on climate change (global warming) have placed renewed emphasis on the "greenhouse gases" (e.g., carbon dioxide and methane). Whether the carbon dioxide from burning fuels is derived from biological sources or fossil sources (e.g., coal, oil, and natural gas) is a significant point of focus. The different solid waste management alternatives—source reduction, recycling, composting, combustion, and landfilling—impact

- Gross Domestic Product (GDP) growth is a measure of services plus manufactured goods that are created and subsequently enter an end of life cycle. Thus, generation of the product components of MSW follows GDP closely, although MSW generation grows at a slower rate than GDP. Yard trimmings generation is in decline due to changes in at-home management practices, while food waste generation is based on population growth and eating habits. The basic forces driving these trends are still in place.

- Recovery of materials for recycling and composting is now a significant and integral part of municipal solid waste management. While recovery of materials and compostables continues to grow, the trends indicate some maturity in this activity, with consequent flattening in the *growth* of recovery becoming apparent by 2000.

- A majority of recovery of materials for recycling from residential and commercial sources (especially commercial sources) is accomplished through a separate infrastructure from solid waste management. Over the last decade, however, more and more recovery is taking place within the context of MSW management infrastructure, e.g., by residential curbside collection and materials recovery facilities. The direct involvement of both communities and private haulers in materials recovery activity has created a whole "new" infrastructure for collection and processing of recyclable materials, especially from residential sources. At the same time, recovery from commercial sources, e.g., office papers, has also begun to flow more through MSW systems. In parallel, recovery of materials and compostables has increased from 17.2 percent of generation in 1990 to 27.0 percent of generation in 1995.

- The number of landfills in operation has declined dramatically, but the capacity of landfills has grown. At the same time, the quantity of MSW landfilled annually is tending to decline over time. This has created more competition in tipping fees and even some cases of financial stress because of declining revenues for communities that own and operate landfills.

- Combustion of MSW in waste-to-energy facilities is essentially flat and is not likely to increase over the next several years. The competition from increased landfill capacity and growing diversion of combustible materials is a key driving force.

- Paper and yard trimmings together constitute about 53 percent of generation and 74 percent of recovery. Other materials—steel, aluminum, glass, plastics, rubber, leather, and textiles—constitute about 38 percent of generation and about 24 percent of recovery. While all components of MSW are potential targets for recovery, the diversion of paper and yard trimmings drives total recovery up faster than the combination of other materials.

Chapter 1

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Chapter 2

SOLID WASTE MANAGEMENT INFRASTRUCTURE

INTRODUCTION AND BACKGROUND

As described in Chapter 1, "modern" municipal solid waste management really did not exist much before 1970. Incineration without pollution controls was common in urban areas, and many residents in towns and rural areas burned their wastes on site. Ash may have remained on site or have been hauled to dumps. Town dumps were not covered daily (often never), and combustibles in the dumps were commonly burned to reduce volume. While collection of refuse was established in major cities at least a century ago, curbside collection of wastes for every home has only become common in the past few decades.

The recycling infrastructure that is in general use now, with convenient curbside collection, processing facilities for both household and commercial recyclables, and community composting programs, was likewise virtually unknown prior to 1970. This does not, however, mean that recycling is something new. Since the first manufacturing plants were established in the United States, basic industries such as paper, steel, and glass manufacturing have used recovered materials as feedstock. Salvage of secondary materials is a very old industry in the U.S., going back to the days of horse-drawn wagons and pushcarts (Darnay 1972).

Residential and Non-Residential Infrastructures for Waste Management

As demonstrated in Chapter 1, MSW from single-family residences amounts to about 51 percent of the total nationwide. MSW from multi-family (over four units) residences makes up about 6 percent of the total, and non-residential MSW (mostly from commercial and institutional sources) makes up the remainder (about 43 percent of the total). This is important because the waste management infrastructures are different depending upon the sources of the MSW.

The most prominent methods currently used for managing MSW are discussed in this chapter. Collection and transport, processing for recycling and composting, and disposal techniques are described for both residential and non-residential MSW. Infrastructure differences in managing residential and non-residential MSW are most apparent in collection and processing, which reflects the differences in mixes of materials and collection conditions.

Developments that may change MSW management techniques in the future are presented later in the chapter.

Public and Private Infrastructures for Waste Management

Collection of MSW from commercial sources and multi-family residences is most often done by private sector haulers, whether the collection is for disposal or for recycling. An estimated 95 percent of MSW from non-residential sources and multi-family households is collected by private firms. However, it is not unusual to find public agencies collecting these wastes, especially in smaller communities.

Collection of MSW from single-family residences is estimated to be about 65 percent through private haulers. In some large cities, residential collection is divided between the public and private sectors. While private haulers may still be gaining in percentage share of residential collection, it is expected that many cities will continue public collection services within the foreseeable future.

Franklin Associates estimates that, in total, 80 percent of MSW collected for disposal or recycling/composting is done by the private sector and that this percentage is increasing. Local governments commonly contract with or franchise private haulers. Also, individuals and homes associations often contract directly with private haulers, especially in suburban areas.

Ownership of the nation's landfills is somewhat more evenly divided, with one recent estimate by Smith Barney that 44 percent of landfilled tonnage goes to government-owned facilities (Waste News 1996). The same source estimated that 37 percent of landfilled tonnage went to private landfills of publicly held companies, while 19 percent went to landfills owned by other private companies. The trend has been toward consolidation of landfill ownership by the large publicly held companies.

Additional discussion of the roles of the public and private sectors in MSW management is included in each section that follows.

OVERVIEW OF CURRENT MSW MANAGEMENT INFRASTRUCTURE

Residential MSW Management

Collection and Transport for Disposal. Collection of single-family generated MSW for disposal is generally done at curbside with rear- or side-loading compaction vehicles called packer trucks. In some areas, collection service is provided house side at the front or rear of the house. Single-family household waste is often collected in bags or cans of about 20 to 30 gallons capacity, which are handled manually by two or three-person crews. In some areas, collection is performed with automated or semi-automated packer trucks requiring special containers that can be attached to mechanical lifting arms for unloading. With semi-automated collection, a container is rolled to the collection vehicle, where a mechanical arm lifts and unloads the container. With fully automated collection, a single crew person inside the vehicle cab operates a mechanical arm which reaches out, picks up, and unloads a special container of, typically, 60 to 90 gallons capacity.

Household MSW collected in packer trucks is often referred to as refuse/trash. Collection of refuse/trash usually occurs once or twice each week, although the trend is toward once per week collection in most areas. Bulky items, such as large furniture and appliances, cannot always be placed in packer trucks and must, instead, be collected separately. Bulky waste collection is not as frequent as refuse collection and may be offered only once per month or even less. In some areas, bulky waste collection is offered by appointment only. Some communities offer an annual bulky waste collection. Often scavengers remove a high percentage of the bulky materials set out ahead of the collection for disposal.

Distance is an important factor in determining the means used to transport collected MSW to disposal. If the disposal site is close enough, the collection vehicles usually travel directly from their collection routes to the site with their loads. However, long distances to disposal sites often justify transferring loads from collection vehicles to larger trailer-type vehicles. These transfer vehicles may haul three to four times the quantity contained in a typical packer truck of 25 cubic yards capacity. In addition, a transfer vehicle only requires a one-person crew (the driver), whereas a collection vehicle with a two- or three-person crew has wasted labor during long hauls.

Waste transfer requires the construction and operation of transfer stations, which add to the cost of waste transfer. Wastes are loaded into open-top trailers at some transfer stations. Other transfer stations have stationary compactors, which load and compact waste into enclosed trailers. A recent survey by ***BioCycle*** on solid waste management practices in the U.S. reported 3,123 transfer stations in 1996, a 19 percent increase in one year (Goldstein 1997). The increasing use of transfer stations reflects the decreasing number of landfills (discussed later). In 1996, more transfer stations than MSW landfills were reported for the first time.

Collection of multi-family generated MSW for disposal is much the same as collection from commercial establishments and will be discussed in the section on non-residential MSW management.

Collection for Recycling and Composting. Collection of recyclable materials from residences has several variations, including curbside collection, drop-off sites, buy-back centers, and deposit systems. Each of these is discussed below.

Curbside Collection. Curbside collection of materials from single-family residences for recycling or composting has become a common practice in recent years. Variations exist in materials collected, collection frequency, storage containers, collection vehicles, etc.

Separate collection for composting usually includes yard trimmings collected in the same packer trucks used for refuse collection. Grass clippings and leaves are usually collected in bags, whereas brush and tree trimmings are bundled. Use of paper bags is preferable to nondegradable plastic bags, since the paper bags will compost with the yard trimmings while the nondegradable plastic bags must be removed. The lower cost plastic bags are still much more commonly used, however. (Compostable/degradable bags are available.)

Curbside collection of source-separated recyclables—i.e., curbside recycling—is accomplished in a number of ways. Typically, special-design non-compaction trucks are used to collect household recyclables, which are placed at the curb in dedicated bins/containers of between 14 and 18 gallons. In some programs—mostly in smaller communities—the recyclables are sorted before being placed in different truck compartments. In larger programs, recovered grades of paper are placed in one or more truck compartments and commingled containers in another. The commingled containers are sorted at a materials recovery facility (described later).

A few curbside recycling programs have used packer trucks for recyclables collection. In co-collection programs, recyclables are placed in plastic bags of a designated color and collected in the same vehicle along with refuse. If collected in the same compartment as the refuse, the recyclables must then be separated when unloaded at a transfer station. Collection vehicles with different compartments for refuse and recyclables are sometimes used, which avoids both potential contamination of the recyclables and sorting them from the refuse.

Progress in establishing curbside recycling programs is shown in Table 2-1 and Figure 2-1 based on annual surveys of programs by ***BioCycle***. In terms of numbers of programs, the high growth rates shown for the early 1990s appear to drop substantially between 1993 and 1995. However, a sharp increase is shown between 1995 and 1996, which is partly due to a dramatic change in the number of programs reported for New York. The latest ***BioCycle*** survey (Goldstein 1997) indicates a more reliable source for the current New York number, which suggests that the number of programs reported nationally for 1995 (and perhaps earlier) may have been too low.

The population served by curbside recycling programs has grown at an even faster rate than the number of programs. In 1990, a reported 36.4 million persons in the U.S. were served by curbside recycling programs, whereas the population served in 1996 was reported at nearly 135 million. These figures represent 26 percent of the population in 1990 and 51 percent in 1996.

Drop-off Centers. Drop-off centers typically collect residential recyclables, although some accept materials from businesses. There is a very wide range of locations for drop-off centers: grocery and other retail stores, sheltered workshops, other charitable organizations, city-sponsored sites, etc. Types of

Table 2-1

CURBSIDE COLLECTION OF RECYCLABLE MATERIALS, 1990 TO 1996

	1990	1991	1992	1993	1994	1995	1996
Number of Programs	2,709	3,959	5,404	6,676	7,263	7,375	8,817
Annual % growth		46%	36%	24%	9%	2%	20%
Population Served (thousands)	36,416	64,849	78,073	102,092	108,173	121,335	134,630
Annual % growth		78%	20%	31%	6%	12%	11%
% of Population Served*	26%	39%	40%	42%	43%	48%	51%

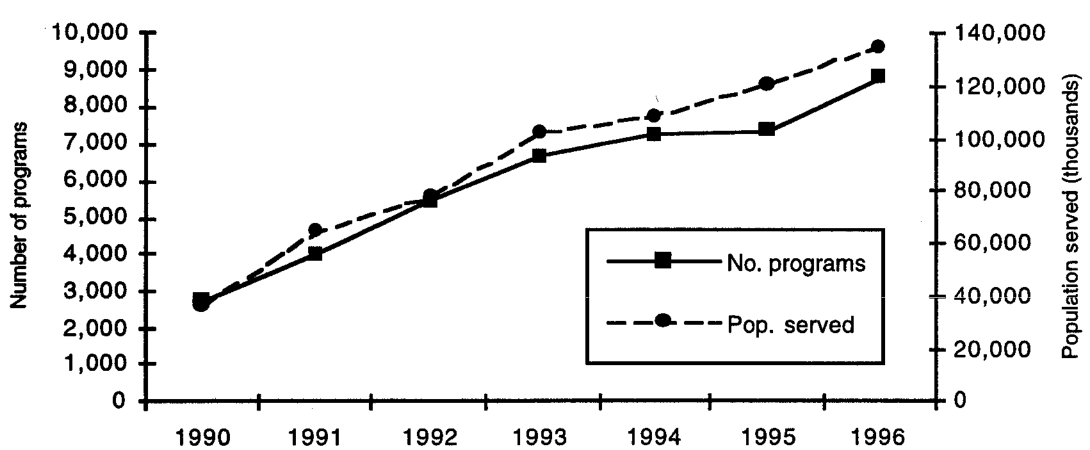
* Percent of population served calculated based on population of states reporting data.

Source: BioCycle survey 1997 plus earlier editions of the same survey. Population from U.S. Bureau of the Census. Percentages by Franklin Associates.

materials accepted also vary widely. Drop-off operations at retail stores are often quite limited in the types of materials accepted, whereas municipal drop-off operations may accept a broad variety of recyclables.

Drop-off centers that accept several materials are usually staffed during the times they are open to the public. This is necessary to prevent contamination of the accepted materials, which must be sorted when placed in the drop-off containers. The sorted materials at a large drop-off center may be placed in roll-off containers. The roll-offs are each loaded on a truck chassis and hauled to a processing facility, where the materials are emptied. Small drop-off operations may simply include a recycling truck with compartments for different materials.

Figure 2-1. Number of curbside collection programs, 1990 to 1996



Multi-material drop-off centers vary in collection arrangements and usually have limited hours of operation.

While it is difficult to quantify numbers of drop-off centers in the U.S., the ***BioCycle*** survey identified 10,436 centers in 1996, a 19 percent increase from 1995 (Goldstein 1997). In some areas, especially those that are sparsely populated, drop-off centers may be the only option for collection of recyclable materials. In other areas, drop-off centers supplement other collection methods.

Buy-back Centers. A buy-back center is typically a commercial operation that pays those who bring in recovered materials. This could include scrap metal dealers, centers set up by major corporations to recover aluminum cans, individual entrepreneurs, waste haulers, or paper dealers. Materials brought to buy-back centers may be collected by individuals, small businesses, charitable organizations, or municipal drop-off centers. Payment may be received for some recyclable materials but not others, depending upon their current market value.

Buy-back centers are sometimes located at recyclables processing facilities. This increases the value of the delivered materials, since there is no added cost to transport the materials for processing.

While buy-back centers have been an important part of recovery systems for many materials, in the past few years the numbers of buy-backs have been declining (Powell 1996). Many small centers have gone out of business, and even some major corporations have cut back on the number of buy-back centers. This phenomenon can be attributed in large part to the rapid development of curbside recycling collection programs in the 1990s. (See Figure 2-1.) Recently, depressed markets for recovered materials have contributed to the decline in numbers of buy-back centers.

Deposit Systems. Nine states—Connecticut, Delaware, Iowa, Maine, Massachusetts, Michigan, New York, Oregon, and Vermont—have deposit systems aimed at returns of beverage containers (usually containers for beer and soft drinks). In addition, California has a redemption system that encourages returns of beverage containers; the consumers do not, however, pay deposits in California.

While deposit laws as a recovery mechanism are not a focus of this report, it is important to acknowledge the existence of these laws and their importance in deposit states. However, recovered tonnage of beverage containers through deposits is very small compared to total recovery of materials.

No new deposit laws have been enacted since the early 1980s, although the California redemption law is more recent. (Some existing laws have been modified.) While the deposit laws were originally enacted as litter control measures, they evolved to place recycling as the primary focus. As noted earlier, curbside recycling collection programs have become very popular in the past few years, providing a more convenient way for people to collect beverage containers and other recyclable materials. Rigorous analyses have shown that the presence of a deposit law has a negative effect on the economics of curbside recycling programs because revenue is drained away from these programs by removal of beverage containers (Franklin 1996).

Processing for Recycling and Composting. Several techniques are used for processing recyclables and compostables from residential MSW. These are dependent upon the manner in which the materials are collected.

Materials Recovery Facilities. The ability to process commingled recyclables collected in curbside recycling programs is a distinguishing characteristic of a materials recovery facility (MRF). In addition to the processing steps necessary to prepare sorted MSW recyclables for sale to end-user markets (baling, crushing, etc.), sorting the commingled materials must be accomplished first. MRFs can be high technology, with mechanized processes, or they can be low technology, with most of the sorting performed manually.

MRFs have become increasingly prevalent (Table 2-2 and Figure 2-2). In 1995, 310 MRFs serving over 40 percent of the total U.S. population were reported. This was more than twice the population served by MRFs three years earlier.

Table 2-2

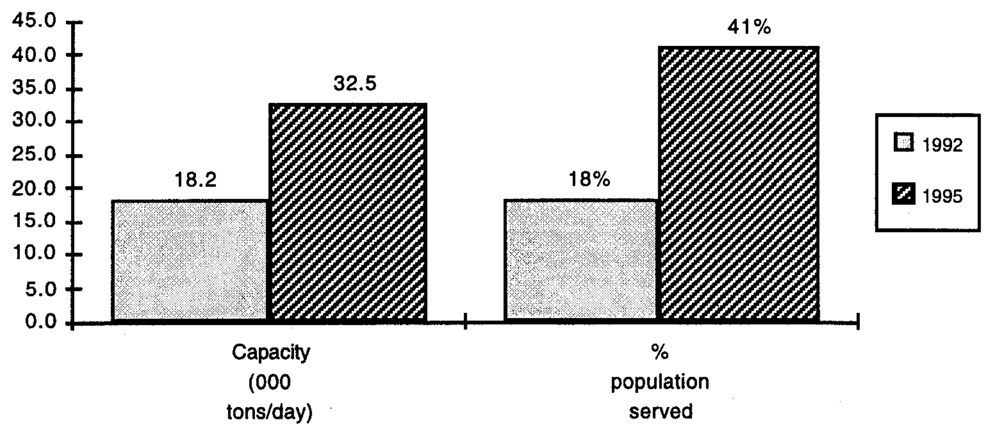
MATERIALS RECOVERY FACILITIES, 1992 AND 1995

	1992	1995
Number of Facilities		
Low Tech	116	196
High Tech	56	114
Total	172	310
Annual % growth		22%
Capacity (tons per day)	18,200	32,500
Annual % growth		21%
Population Served (thousands)	44,929	106,798
Annual % growth		33%
% of Population Served*	18%	41%
Annual % growth		32%

* Based on total U.S. population.

Source: Government Advisory Associates, 1992, 1995, 1996.
Percentage calculations by Franklin Associates.

Figure 2-2. Materials recovery facilities, 1992 and 1995



Ownership of MRFs in 1995 was both public and private, but private ownership was much more prevalent (Figure 2-3). Operation of MRFs was even more heavily weighted toward the private sector. Even when a public agency owns a MRF, they often contract operation to the private sector. Some MRFs were closed in 1996 and 1997 and others changed hands, but 1996 data were not available to make a determination of net change since 1995.

Recyclables Processing Facilities. A recyclables processing facility (RPF) is used to process source separated recyclable materials for sale to end-user markets. It differs from a MRF in that there is no sorting of commingled recyclables. RPFs have been used for many years to process recyclables from commercial establishments and residential drop-off facilities. More recently, they have also been used to process recyclables from curbside recycling programs that deliver sorted materials. The number of RPFs is unknown, but there are many more RPFs than MRFs. Some RPFs process a limited number of materials—only certain grades of recovered paper in some cases.

Mixed Waste Processing. While less common than conventional MRFs, there are a number of facilities in the United States that receive and process unsorted MSW (Table 2-3). The MSW is collected in the same manner as

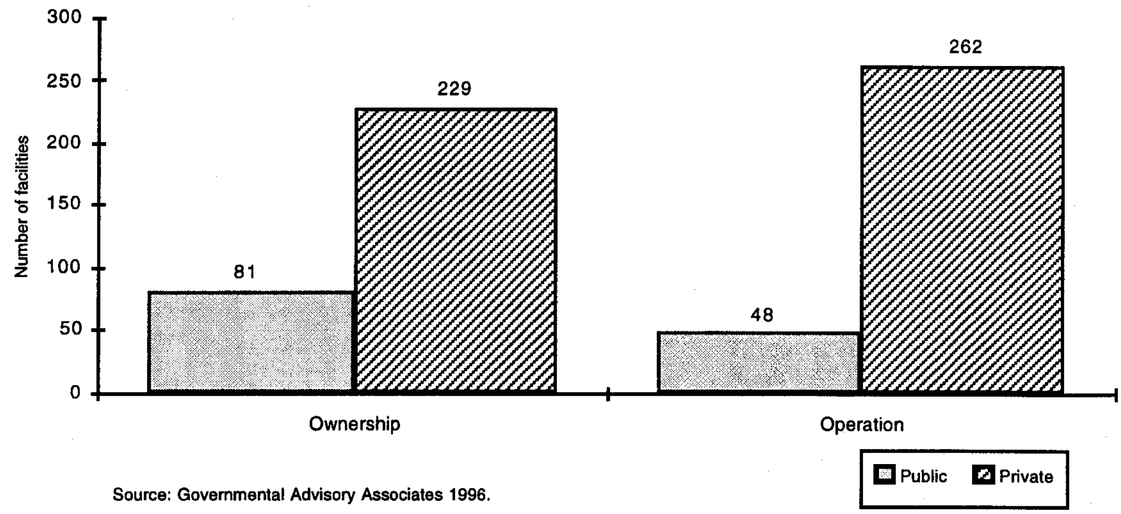
Table 2-3

MIXED WASTE PROCESSING FACILITIES, 1996

Number of Facilities	31
Capacity (tons per day)	20,240

Source: Government Advisory Associates, 1996.

Figure 2-3. Ownership and operation of MRFs, 1995



Source: Governmental Advisory Associates 1996.

when disposed in a landfill or combustion facility. Recyclable materials are sorted from the MSW, and a fuel or compost product may also be produced. These facilities are sometimes referred to as "dirty MRFs."

There is a fundamental conflict of objectives when mixed waste processing is practiced at the community level. The community has the objective of driving down collection costs, but retrieving (diverting) as much recyclable material as possible, usually in a "dirty MRF." By contrast, an industry seeking or willing to use recovered materials for recycling finds that the contamination of the recovered materials, especially paper and glass, is so great that they are marginally acceptable or unacceptable. Consequently, only minimal diversion can take place.

In the 1980s, a few communities—e.g., Rochester County, New York and Dade County, Florida—engaged in highly engineered systems to extract high quality materials from mixed MSW. In some cases, the processing was technically successful but the costs were astronomical compared to market value of the recovered materials or alternative disposal costs. These early attempts failed to achieve the goals sought, and the systems were eventually shut down.

A resurgence of efforts once again arose in the 1990s, with about the same results. The number of mixed waste processing facilities in the U.S. has been flat to down the past few years, and many of the facilities built have shut down (Berenyi 1995). A notable example was in San Diego County, where a 550,000 ton per year capacity facility was built at a cost of $134 million. The operation failed when cities in the area refused to ship waste to the facility because its tipping fees ($55 per ton) were higher than available landfills and waste-to-energy facilities (Apotheker 1995).

Fewer mixed waste processing facilities were reported operating in 1996 than in previous years. As noted above, this may be partly due to difficulties in marketing the sorted recyclables and fuel or compost products. The market for refuse-derived fuel (RDF) is limited, since few power plants or other facilities are equipped to handle the material. Compost from mixed waste processing facilities has, typically, included contaminants—e.g., bits of plastic and glass (Goldstein 1996)—which make the material difficult to market. At best, the compost must usually be given away. Consequently, the use of mixed waste collection and processing remains an option to be considered to achieve additional diversion, but is not an option that will be significant for the balance of this century.

MSW Composting Facilities. MSW composting facilities are frequently mixed waste processing facilities that compost selected organic fractions of the incoming MSW after sorting. However, five of the 15 operating MSW composting facilities in 1996 (Table 2-4) compost only source separated biological organic portions of MSW. These source separated organics are collected separately and delivered to the composting facility.

Table 2-4

MSW COMPOSTING FACILITIES, 1990 TO 1996

	1990	1994	1995	1996
Number of Facilities	10	17	17	15
Annual % change		14%	0%	-12%
MSW Processed (tons per day)	840	1,300	770	720
Annual % change		12%	-41%	-6%
Capacity (tons per day)*	2,160	2,540	1,615	1,531
Annual % change		4%	-36%	-5%

* Capacity includes facilities temporarily shut down.
The decrease in capacity from 1994 to 1995 reflects the change in status of the Pembroke Pines, FL facility from temporarily to permanently closed, and also the closure of the Baltimore, MD facility.

Source: Goldstein 1990, 1994, and 1996, and Steuteville 1995.
Percentage calculations by Franklin Associates.

Materials composted may include paper, food wastes, yard trimmings and wood wastes. These materials are decomposed biologically under aerobic conditions, leaving a humus material (compost) that may be used as a mulch or soil conditioner. Inorganic materials (mostly glass and metals) and certain organic materials (such as plastics, rubber, leather and textiles) decompose very little or not at all and are considered contaminants if found in the compost. Compost from mixed waste processing facilities often contains contaminants, which lowers its value.

MSW composting facilities for selected years 1990 through 1996 are shown in Table 2-4. MSW composting activity has declined over the last few years. Part of the decline is due to the closing of the largest MSW composting facility ever designed (2,600 tons per week) in early 1995.

Yard Trimmings Composting. The most prevalent type of composting in the U.S. today is yard trimmings composting. Leaves, grass clippings, and trimmings from trees and brush are collected separately for composting. As Table 2-5 shows, the number of reported yard trimmings composting programs more than doubled from 1990 to 1996—an increase equivalent to 15 percent per year. However, it is also of note that the reported number of these programs decreased slightly between 1995 and 1996 (Goldstein 1997). This was attributed largely to better reporting and substituting the use of larger composting operations for smaller ones.

Table 2-5

YARD TRIMMINGS COMPOSTING PROGRAMS, 1990 AND 1995

	1990	**1996**
Number of Programs	1,410	3,260
Annual % growth		15%

Source: BioCycle Survey, 1997 and earlier editions.

Composting yard trimmings is commonly done by constructing windrows that are periodically turned to provide sufficient aeration to keep the process aerobic. In order to shorten the time for developing compost, efforts are often made to control aeration, temperature, and moisture levels necessary for optimum biological decomposition. Shredding and mixing leaves and wood trimmings with grass clippings also benefits decomposition. Still, land requirements can be extensive for large yard trimmings composting operations.

More complex composting operations using in-vessel and/or static pile techniques can reduce land requirements. However, these techniques are more commonly used with mixed MSW composting operations.

Disposal. Residential MSW to be disposed may be land disposed or combusted, as described below.

Landfilling. The most common method of disposing of MSW is landfilling. In years past, this usually involved dumping waste at a specified location and occasionally covering it with soil. More stringent regulations—primarily EPA's RCRA regulations—now require engineered sites designed and operated to minimize the potential for health risks and environmental pollution. Consequently, landfilling costs have increased substantially, and small landfills are becoming rare as the new standards often make them prohibitively expensive.

An on-going survey conducted by the Environmental Industry Associations (EIA) provides some interesting insights into what has been happening to landfill capacity in the United States (Waste Age 1996). While the numbers of landfills were declining from 7,575 in 1988 to 2,893 in 1995, landfill disposal capacity actually increased between 1991 and 1995. Thirty-eight states had greater than 10 years of remaining landfill capacity in 1995, while 21 states had more than 10 years of landfill capacity in 1991. (See Table 2-6 and Figure 2-4).

Table 2-6

LANDFILL CAPACITY, 1991 AND 1995

	1991	1995
Number of Landfills	5,726	2,893
Annual % change		-16%
Remaining Years of Landfill Capacity*		
<5 years	10	2
5–10 years	19	10
>10 years	21	38

* Numbers of states.

Source: Waste Age 1996.
Percentage calculations by Franklin Associates.

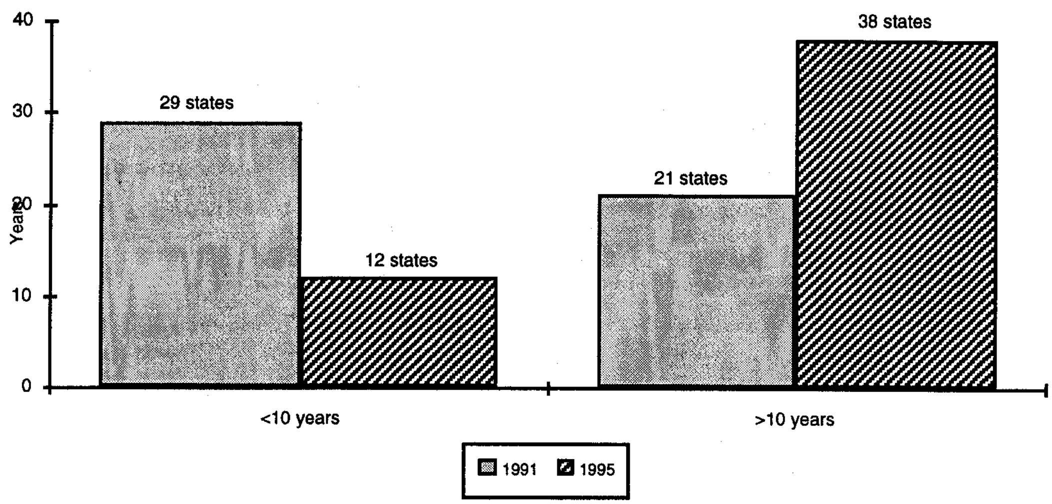
A recent report issued by the Illinois EPA (Waste News 1997) illustrates these trends. From 1987 to 1995, the number of landfills in Illinois decreased from 146 to 58. At the same time, landfill capacity increased from 274 million cubic yards to 474 million cubic yards. The rate of increase in 1995 was 31 percent. The report editor estimated that the state has landfill capacity for the next 10 years even if no new landfills are sited.

The EIA survey authors identified the following reasons for the decline in numbers of landfills while, at the same time, capacity increased:

- Promulgation and implementation of federal RCRA criteria in 1991. The majority of states reported significant closures of MSW landfills when federal and/or state criteria were enforced.

- Building of larger landfills to achieve economies of scale necessary to meet the high costs of complying with the new environmental standards.

Figure 2-4. Remaining years of landfill capacity, by states, 1991 and 1995



- Increased recycling programs and other diversions from landfills, which reduce utilization of existing capacity and thus extend the life of landfills.

The EIA survey also found that landfill tipping fees increased about 7 percent per year between 1992 and 1995, or about double the current rate of inflation. The authors predict that this trend will continue, although they predict that prices in the Mid-Atlantic Region should remain relatively constant.

Tipping fees at landfills can vary widely based on a number of factors such as competition in an area, mandated fees, taxes, profit margins, and other factors. Also, tipping fees may or may not reflect true costs over the life of the landfill.

Landspreading. Landspreading is not used for disposal of mixed MSW. However, separately collected leaves and grass clippings are sometimes spread on open areas (such as farm land). They are typically incorporated into the soil—through plowing or disking—where they will eventually decompose.

Landspreading of yard trimmings accounts for a very small portion of MSW disposal.

Combustion. Waste-to-energy facilities produce salable steam, or more likely, electricity. Also, they normally recover ferrous metals from incoming wastes as well as from the combustion residue. (In some instances, other materials are recovered as well.) As demonstrated in Chapter 1, combustion as an MSW disposal option was quite prevalent up through the early 1970s, then declined as air pollution control measures were enforced and the old incinerators were mostly closed. Energy recovery experienced a resurgence in the

1980s, but addition of new capacity has been relatively slow in the 1990s. There are several reasons for this slow growth:

- Costs are high relative to other MSW management alternatives, especially landfilling. Increased requirements for air pollution controls and ash disposal account for much of the cost increase.

- Prices for fossil fuels have been relatively low compared to those experienced in the 1970s, making it more difficult to achieve sufficient revenues from sale of energy to offset increased costs.

- There has been vocal community opposition to siting combustion facilities in many parts of the country, thus politicizing the siting process. Many communities and private companies have experienced cancellations, long delays, and even changes in elected officials over a planned combustion plant.

A comparison of MSW combustion facilities in 1990 and 1996 is shown in Table 2-7 and Figure 2-5. The number of operational combustion facilities declined by an equivalent annual average of 3 percent in those six years; both waste-to-energy facilities (combustion with energy recovery) and incinerators (no energy recovery) declined. Capacity for combustion did, however, increase by an equivalent annual average of nearly 2 percent in the same period. Published information on individual facility throughput is generally not available, so a good assumption is that they operate at 85 percent of capacity.

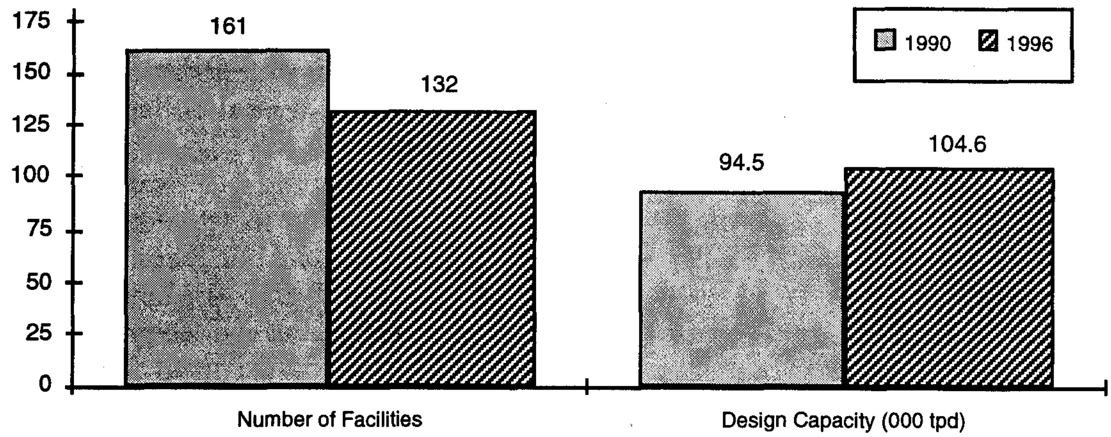
Table 2-7

OPERATIONAL MSW COMBUSTION FACILITIES
1990 and 1996

	1990	**1996**
Number of Facilities		
Waste-to-Energy	125	112
Incinerators	36	20
Total	161	132
Annual % change		-3%
Design Capacity (tons per day)		
Waste-to-Energy	87,845	101,750
Incinerators	6,640	2,820
Total	94,485	104,570
Annual % growth		2%

Source: Waste Age 1990; IWSA 1996.
Percentage calculations by Franklin Associates.

Figure 2-5. Operational MSW combustion facilities, 1990 and 1996



The time frame for implementing MSW combustion facilities is generally lengthy due to reasons outlined above. An interesting comparison can be made, once again, between 1990 and 1996. Of 74 facilities listed as under construction or in advanced planning stages in 1990, only 30 percent were listed as operational in 1996. Sixty-four percent had dropped off the list altogether; the remainder were listed as either in advanced planning or under construction.

Since not all MSW can be combusted, a residue/ash remains after combustion. Depending upon the facility and the process used to quench the ash, 20 to 30 percent or more by weight and 10 per cent by volume of the quantity combusted will remain for disposal. Thus, landfilling of ash is required, but the volume is relatively small compared to the incoming waste. New generations of waste-to-energy facilities will be more efficient than those installed in the 1980s.

Non-Residential MSW Management

Collection and Transport for Disposal. Wastes destined for disposal from commercial and institutional establishments as well as multi-family residences are normally collected from "dumpsters" or larger roll-off containers. Dumpster-type containers are typically between two and eight cubic yards capacity and are commonly used by small retail establishments and multi-family complexes. They are emptied into front- or rear-loading packer trucks with semi-automated mechanical lifting arms.

Roll-off containers of between 20 and 42 cubic yards capacity are frequently used by large department stores, grocery stores, and restaurants that generate more waste. Enclosed roll-off containers are often used in conjunction with a stationary compactor that compresses the waste into the container. The roll-off is then hoisted onto a truck chassis for transport to a disposal site or transfer station, where the wastes are emptied.

Collection of non-residential MSW for disposal can be more or less expensive than corresponding residential collection. When large quantities are collected at a single stop—e.g., from roll-off containers or large dumpsters—collection is often less expensive. Conversely, small quantities located apart from other collections may be more expensive than residential collection.

Non-residential MSW may be taken to the same disposal site or transfer station as residential MSW. However, the distance to the disposal site may need to be further for non-residential loads than for residential loads before waste transfer is cost effective. One reason for this is that non-residential loads in front-end loading packers and roll-off containers are sometimes larger than residential loads. In addition, one-person collection crews are often used for non-residential collection, which further lowers travel costs.

Collection for Recycling and Composting. Non-residential MSW recovery for recycling consists mostly of old corrugated containers (OCC) and office papers. In the private sector, recovery of these paper grades must usually be shown to be more cost effective than disposal. (This generally means cost savings over conventional solid waste services.)

More OCC is recovered than any other MSW recyclable, and most of the recovery is from commercial establishments. Large generators of OCC often bale the material before it is collected, while some use enclosed roll-off containers with stationary compactors. Small generators will sometimes place OCC boxes that have been flattened into dumpsters that are emptied into front- or rear-loading packer trucks.

Recovery of high grade office paper has become more prominent in recent years. Convenient receptacles where office employees can deposit recovered paper are needed for high participation and to minimize costs. Ultimately, the separated paper is transferred to larger containers (e.g., gaylords) for collection and transport to a processor. If inside storage space is not available, recovered office paper may be placed in dumpsters and collected in packer trucks. Very large generators of used office paper sometimes store the material in enclosed roll-off containers.

Other recyclables, including beverage containers, frequently are collected from non-residential establishments, as well. Restaurants and bars, for example, may have substantial quantities of bottles and cans that are periodically collected separately for recycling. Other business establishments may have designated bins where employees can place cans and bottles. If the quantities collected are small, volunteers may haul them to drop-off or buy-back centers used primarily for collection of residential recyclables.

Separate collection of non-residential MSW for composting is also comparatively small. However, yard management services often take yard trimmings from business and institutional establishments to compost facilities instead of landfills. Also, food wastes are occasionally collected separately for composting or for processing into animal feed.

(Note: A good database on collection is available in documents from a number of associations, e.g., the Solid Waste Association of North America (SWANA), the National Solid Wastes Management Association (NSWMA), and the American Plastics Council (APC), as well as the U.S. EPA.)

Processing for Recycling and Composting. Since recovery of recyclables from non-residential sources normally includes collection of pre-sorted materials, the materials are usually processed at a recyclables processing facility (RPF). Some non-residential recyclables are taken to MRFs—even when no sorting is needed—if the MRF is close or otherwise offers a cost advantage.

Non-residential MSW is also taken to mixed waste processing facilities. Both residential and non-residential MSW is processed for recovery of recyclables and, typically, production of refuse-derived fuel and/or compost.

As noted above, yard trimmings composting facilities may include yard trimmings from non-residential sources. This is particularly true in areas where yard trimmings are banned from landfills.

Disposal. Disposal of MSW from both residential and non-residential sources is usually at the same facility. As noted previously for residential MSW, landfilling is the most common disposal method, but combustion facilities are used in some areas.

MSW MANAGEMENT INFRASTRUCTURE DEVELOPMENTS

This section focuses on recent developments that could affect future MSW management infrastructure in the U.S. These developments are a function of changing solid waste management needs and goals as well as advances in technology that are partly in response to those needs and goals.

Collection and Transport

The combination of collection and transportation has long been the most expensive part of managing residential MSW—both for quantities disposed and separately collected recyclables/compostables. It is usually the most costly part of managing non-residential MSW as well. In recent years, the closing of local landfills in favor of larger but more distant disposal sites and increased recycling and composting have added even more cost to handling MSW. Considerable attention is, therefore, being given to measures designed to reduce MSW collection and hauling costs.

Waste Transfer. As noted previously, the number of transfer stations outnumbered MSW landfills for the first time in 1996. This is a reflection of the vastly decreased number of landfills over the last five years. As distances to landfills increase, transferring wastes to tractor-trailer vehicles (or, in some cases, rail cars) often becomes more economical than hauling with collection trucks.

The decrease in MSW landfills is slowing now that the federal Subtitle D regulations have essentially taken full effect (Goldstein 1997). This may also reduce the number of new transfer stations in the next few years. However, in some highly populated areas, such as New York City, closure of large landfills will soon necessitate waste transfer to sites much further away. Where transfer distances are substantial, rail haul is expected to play an increasing role in minimizing waste transfer costs (Trotti 1996).

Collection. On-route collection, in most cases, is still more costly than transporting the wastes afterward. A wide variety of collection vehicles—ranging from compaction to non-compaction, manual loading to fully automated loading, etc.—have been available for several years. Choosing between these is a function of the type of wastes collected, the physical characteristics of the collection neighborhood, and other factors.

The emergence of separate collections of household wastes that may be recycled or composted has added both complexity and cost to residential waste collection. Separate collections of refuse, recyclables and yard trimmings with as many trucks *is more expensive than collecting them mixed together as one waste stream.*

Efforts have focused on co-collection of source-separated household waste streams in order to reduce collection and transportation costs. Initial co-collection attempts involved placing bags of recyclables in the same compaction compartment as refuse. This approach requires a transfer station where the bags of recyclables can be sorted from the refuse. Problems with this approach include:

- recyclables contamination
- extra costs of pulling the bags of recyclables from the refuse
- need for an on-site MRF or recyclables transfer.

In addition, the public appears reluctant to accept this concept, as evidenced by low participation levels in at least some areas where it has been used. The program was dropped in Omaha, Nebraska and is troubled with low household participation in Chicago (Farrell 1996), although the participation level in 1997 is reported to be higher than the 25 percent level experienced in 1996 (White 1997).

More recently, collection vehicles with separate compartments for refuse and recyclables (or compostables such as yard trimmings) have been offered. These eliminate the contamination problems and the necessity of separating the recyclables/compostables from the refuse after unloading. Co-collection in different compartments is more time consuming, of course, and it is important that the separate compartments be correctly proportioned. For example, any collection savings may be lost if the recyclables compartments are filled while the refuse compaction compartment remains half empty—or vice versa.

Fully automated packer trucks for refuse collection are becoming more prominent partly because of reduced labor costs. In residential areas where they can be maneuvered to pick up and empty special containers, the need for only one crew member (the driver) reduces labor requirements substantially. An added advantage is the reduced risk of injury and worker compensation claims. A drawback of fully automated collection is the need for special containers that may be larger than needed sometimes and too small at other times—e.g., during periods of yard trimmings setouts. Automated trucks are less conducive to volume-based pricing, as well, but are ideal for weight-based pricing.

Truck manufacturers are now experimenting with fully automated trucks with dual compartments for co-collection (Merrill 1997). These trucks either pick up a split automated container that is emptied into a two-compartment body or allow the driver to direct which compartment a container is emptied into.

Efforts to meet the broad range of MSW collection needs (that now exist) while minimizing costs will continue. Increased automation and co-collection of residential MSW is expected to occur, although progress may be slow and these options will not be applicable in all areas. Advanced technology is leading to trucks with less downtime and longer life. The need for trucks with larger payloads is also being addressed as haul distances increase. Compactors are sometimes being used on recyclables collection trucks to reduce the volume of low-density materials such as plastic containers.

Other efficiencies not directly related to improvements in technology will also be achieved. For example, an area of major importance in containing waste collection costs is to minimize the number of collection stops and drive-bys. One method to accomplish this is by reducing the frequency of collections. Household refuse collection, for instance, is normally needed only once per week and, in some cases, may only be needed every other week (Powell 1996). Recyclables collection costs can also be reduced if households are educated to set out only full containers and/or agree to bi-weekly collection.

Processing for Recycling and Composting

The increases in recovery of recyclables and compostables from residential MSW over the last decade have been responsible for many of the changes occurring in the solid waste management infrastructure. Separate collection and processing of source separated materials has become accepted practice in most urban areas, and this trend continues.

The increase in recovery of residential MSW has also led to increased costs. Recyclables processing and composting facilities represent a major part of recovery costs and must be considered when examining ways to minimize the costs of managing residential MSW.

Recyclables Processing. MRFs are the primary facilities processing separately collected residential recyclables from curbside recycling programs. Larger MRFs are more cost effective than smaller ones. As such, smaller communities implementing curbside recycling generally do not collect commingled recyclables that require sorting. Pre-sorted residential recyclables (including those collected through drop-off/buy-back programs) are frequently processed at RPFs instead of MRFs. MSW recyclables are also recovered in mixed waste processing facilities, although recovery by this technique is small by comparison.

In the last few years, the technology for mechanical separation of commingled containers at MRFs has developed rapidly (Apotheker July 1996). Virtually every MRF has magnetic separation of steel from mixed recyclables. Some older technologies are becoming more affordable, and technology advances will lower the costs of sorting commingled containers at larger MRFs in particular. Those that process at least 100 tons of containers per day will be in the best position to take full advantage of the potential cost savings.

Advances in automation and MRF design may also improve the marketability of recovered paper (Apotheker April 1996). In addition to improved sorting techniques, some MRF operators are reported to be considering the addition of small-scale pulping and deinking systems. This would allow the sale of a more valuable pulp product instead of recovered paper. The added value of this product would have to be weighed against the added cost of producing it.

The technology advances for sorting materials at MRFs may have applicability at mixed waste processing facilities, possibly increasing the number of recyclables recovered. The contamination problems for recyclables recovered from mixed wastes are a separate problem. These may be partly alleviated by sorters that remove visible contaminants attached to the recyclables.

The advances in recyclables sorting technology should increase the number of high-tech MRFs in the years ahead and improve curbside recycling economics in larger communities. For smaller communities, where curbside recycling quantities are less, collection of truckside sorted materials may still remain more cost effective than building a MRF.

New MRFs are frequently being built adjacent to other MSW facilities (Trotti 1996). This increases the flexibility for sharing equipment and personnel. In addition, the cost effectiveness of co-collection is affected by the nearness of facilities receiving each waste stream. If recyclables and refuse are co-collected, it is important that the facilities receiving each be located near one another to avoid extra travel.

MRFs may sometimes be designed to serve as collection centers for household hazardous wastes (HHW) as well. Again, economies can be achieved through joint use of personnel and infrastructure.

Composting. Composting is reported to be the fastest growing element of solid waste management (Powell 1997). Yard trimmings represent over 70 percent of compost feedstocks according to The Composting Council, accounting for most of the recent growth in composting. As noted previously, mixed MSW composting activity has declined over the last few years, although new approaches offer hope for the future.

The most difficult problems in composting appear to be:

- odor control
- contaminants in the compost product
- siting the composting facility
- finding suitable compost markets.

Enclosed composting facilities may employ biofilters or other techniques to control odors. Most yard trimmings facilities are outside windrow operations and must rely on different methods than enclosed facilities. The Composting Council and others are conducting projects to determine operational practices that will minimize odor generation and the complaints that result (Powell 1997). Maintaining outside composting operations at least a few hundred yards from residences is advisable. Also, the use of several small operations appears preferable to one large facility in controlling odors (Bader 1996).

Both odor control and poor-quality compost containing contaminants have caused facilities composting MSW to fail (O'Connell 1997). The contaminants problem is prevalent in facilities that use mixed waste processing to obtain a compost feedstock. Processes to remove non-compostable materials are seldom sufficient to prevent bits of plastic, glass, and other undesirable materials from ending up in the final compost. This often leads to a product with very limited marketability.

Collection of source separated compostable materials from MSW is being done in a few areas and is being considered in others. In addition to yard trimmings, other biologically based organic materials such as paper and food wastes are collected and composted together. This approach eliminates sorting from a mixed waste feedstock and leads to a cleaner compost product.

Work is underway in developing markets for compost in agricultural areas (Powell 1997). Urban-derived composts are becoming of interest to farm operations, which represent a potentially vast market for compost. This relationship also affords opportunities for co-composting. Mixing yard debris with manure, for example, has proven effective in some areas. Co-composting with wastewater treatment sludges could also increase as the agricultural market for compost improves.

In addition to compost, mulch from wood wastes can also be marketed from many composting facilities. While incoming wood trimmings may be composted with leaves and grass clippings, they may also be chipped or shredded separately for use as mulch. This adds to the ability to market all of the materials from the facilities.

For communities that need or desire to minimize landfilling, composting by itself or in combination with other recycling techniques and source reduction offers the greatest potential for diversion short of combustion. In addition, yard trimmings composting is frequently shown to be more cost effective than curbside recycling (see Chapter 3). For these reasons, composting should continue to be a prominent measure for diverting MSW and certain other wastes—e.g., municipal wastewater treatment sludge—from land disposal.

Mixed waste composting and mixed organics (paper, food wastes, yard trimmings) composting are still developing. These options, which are under investigation at the University of Wisconsin and other locations, could become more significant in the next few years.

Yard trimmings facilities should continue to dominate in terms of numbers of composting operations and quantities composted. However, the number of states with landfilling bans on yard trimmings has not been increasing of late, and this may slow the increase in yard trimmings composting. Most yard trimmings composting operations will continue as outside windrow operations to minimize costs. Relatively secluded locations, including old landfill sites, will be used for composting.

Source Reduction

Measures to reduce the generation of MSW—often referred to as source reduction (or waste prevention)—can affect the MSW management infrastructure. Both the size and design of waste management systems are determined by the types and quantities of wastes that must be managed. Local governments and individual households are limited in their ability to achieve source reduction. However, certain measures such as volume- or weight-based pricing on refuse collection and promotion (including education) of methods to reduce household wastes can have significant effects.

The most effective means of reducing MSW from single-family households is home management of yard trimmings. Grasscycling (i.e., allowing grass clippings to remain and decompose on the lawn) and backyard composting of leaves with grass clippings, garden wastes, or selected food wastes can reduce household MSW by 25 percent or more (by weight).

Home management of yard trimmings through composting and grasscycling has increased in recent years as demonstrated by the declining quantity of yard trimmings (EPA 1997). Some of this activity has occurred without cost incentives, while some is in response to the potential to save on MSW management costs. In states with landfill bans on yard trimmings, separate collection of yard trimmings for composting is often available only by subscription at a fee. In other states, some communities charge extra for collection of yard trimmings or include them in volume- or weight-based pricing for refuse collection.

Sales of mulching mowers and distributions of backyard composting bins suggest expanding interest in home management of leaves and grass. This affects not only the quantities but the composition of yard trimmings at composting facilities. For instance, a larger percentage of the feedstock materials will be tree and brush trimmings, which are more difficult for households to manage or compost at home. Equipment, space needs, and the marketing of mulch versus compost can be impacted at composting facilities by home management of yard trimmings.

Source reduction efforts at businesses also appear to be gaining momentum. Electronic data interchange, double-sided copying, and greater use of reusable items is being adopted by companies as part of cost-effective business practices (Bader 1996).

U.S. manufacturers have implemented many source reduction measures. Durable goods such as refrigerators often weigh less than previous models due, for example, to improved insulation. Newspaper publishers have instituted measures to reduce the amount of newsprint used in printing newspapers. In the category of packaging, many changes have been instituted, including reducing the weight of packages while still delivering the same amount of product, concentrating liquid and powder products such as detergents, and introduction of some new refillable containers.

Disposal

Regardless of the amount of source reduction and recovery for recycling and composting that occurs, large quantities of MSW will remain for disposal—primarily through combustion or landfilling.

Combustion. As noted earlier in this chapter, combustion of MSW appears to have increased at a very slow rate in the 1990s, and the number of facilities in operation has actually decreased. Still, combustion is the dominant method of MSW disposal in the New England states (Goldstein 1997) and will continue to be a prominent disposal method in the U.S. within the foreseeable future.

Over 97 percent of MSW combustion capacity is in waste-to-energy facilities, and the trend in this direction suggests that virtually all new combustion capacity will include energy recovery. Fluidized-bed combustion facilities have attracted attention for use in MSW combustion, but the expected proliferation of these facilities has failed to occur (Bader 1996). Mixed waste processing facilities frequently produce a refuse-derived fuel (RDF) for use in existing boilers or dedicated combustion units, but the impact of RDF will probably remain small for the foreseeable future.

Current conditions suggest that MSW combustion will do little more than continue at current levels within the next few years. This could change only in the unlikely event of a dramatic increase in the cost of energy and/or renewed concern over landfill capacity. Even so, it takes a number of years for a new facility to go from planning to operation.

Landfilling. The rapid increases in recovery for recycling and composting in the last 10 years have decreased the quantities of MSW landfilled. This decrease in landfilling coupled with new landfill capacity has virtually eliminated the capacity concerns of a few years ago. With about 57 percent of MSW currently being landfilled in 1995, this disposal method is still the primary means of final disposition for MSW in the U.S.

As noted before, the new landfilling standards resulting from Subtitle D of the Resource Conservation and Recovery Act (RCRA) have dramatically changed landfill design and operation. MSW landfills are far more expensive than before, and very few small landfills are affordable. Large landfill operations are necessary to cost effectively manage the stringent design and operation standards plus final closure and post-closure care requirements. Also, there is a growing pattern of reclamation of closed landfills to be used as recreation areas or other uses.

The trend toward large MSW landfills located at greater distances from population centers will continue. Such "megalandfills" are easier to site and are encouraged by the prospect of attracting waste from great distances because of their low costs (Magnuson 1996).

Increasing post-closure care and liability requirements in some states will lead to an even greater emphasis on landfill designs that assure long-term environmental integrity. Efforts to achieve economies in landfill design and operation are ongoing; for instance, alternative daily covers such as tarps, compost, foundry sand, paper mill sludge, etc. are being tried or considered as substitutes for soil. Some paper mill sludge is reported to have low permeability and can be considered for use as a final cover barrier over wastes to prevent infiltration (Magnuson 1996). Clean compost is useful as part of the top cover layer supporting vegetation over landfills.

Most MSW landfills are expected to continue to employ the "dry cell" approach—i.e., try to minimize moisture infiltrating the buried waste, limiting production of leachate and potential for groundwater contamination. The majority of landfills in the U.S. currently use this approach, which prolongs decomposition of biodegradable landfilled wastes.

There is an alternative approach ("wet cell"), which involves delivering leachate to the waste mass in a controlled manner to control decomposition and minimize future risk. EPA and others have been sponsoring research on this leachate recirculation approach, which promotes rapid stabilization of the landfilled wastes (Delaware 1995, Diaz 1997). Given the long time frame required for permitting and developing landfills, it is unlikely that the wet cell approach will impact solid waste management significantly within the time frame of this report.

Another factor that could affect landfill design and management is the worldwide concern regarding greenhouse gas emissions. Landfills generate and release methane and carbon dioxide (both greenhouse gases) (EPA 1997). Greenhouse gas reduction measures will likely provide a stimulus for increased recovery of landfill gases, which can be an energy source.

Other. Landspreading of leaves and grass clippings on open areas such as farm land may become more prominent in the future as an alternative to composting. Grass clippings and leaves, if worked into the soil, will decompose, enhancing soil properties. Under certain conditions, this can be an alternative to composting or landfilling these yard trimmings and may be less expensive.

More complex approaches to disposal are tried periodically. Pyrolysis processes, for example, use high temperatures in the absence of oxygen to break down organic materials such as plastics and rubber into various gas, liquid and solid components. Gases and liquids from pyrolysis have been used as fuel. A few pyrolysis facilities for MSW were built in the 1970s but were ultimately abandoned. However, pyrolysis is still being considered as a management alternative in some locations (Bader 1996). Past experience suggests that, although technically sound, pyrolysis is expensive and has limited potential as a MSW management alternative.

Public Versus Private Infrastructure

Debate over whether private companies or municipal governments can provide the lowest cost solid waste management services has continued for many years. Municipal governments would seem to have an edge on private operators since they don't pay taxes, can borrow money at less cost, and don't have to show a profit. Private firms, however, maintain that they are more productive and innovative, can take advantage of economies of scale, and even have better worker morale. As pressures to add new services such as recycling/composting occur, private firms have an advantage because of their experience. One financial analyst states that privatization saves municipalities 30 to 40 percent on solid waste services (Bari 1997). Estimates of the growth in privatization of waste management services range from one to 3 percent annually (Russell September 1996; Bari 1997).

Despite the continuing increase in privatization, some communities will remain competitive in providing MSW management services that they are familiar with. Also, there are still occasional reports of the public sector taking business back from the private sector. Thus, the potential for future private sector growth through assumption of services provided by the public sector seems more limited than a few years back.

SUMMARY

Recent developments with implications for the MSW management infrastructure in the U.S. are summarized below.

Source Reduction

- The most effective means of reducing MSW from households is home management of yard trimmings. Backyard composting and grasscycling are both effective source reduction measures that are gaining in popularity.

- Source reduction efforts at businesses, including electronic data interchange, double-sided copying, and greater use of reusable items, appear to be gaining momentum.

- Manufacturers of durable and nondurable goods and packaging have instituted many source reduction measures that appear to have slowed the rate of growth of the MSW stream. This activity will increase.

Collection and Transportation

- Progress in reducing MSW collection and transportation costs through technology improvements has been slow. Trends include increased automation; trucks with longer life, less downtime and larger payloads; co-collection of refuse and recyclables/compostables in dual compartment trucks.

- Other efforts to reduce collection costs (for both refuse and recyclables) include measures to increase on-route efficiencies through reducing collection frequency, educating households to set out full containers, etc.

- Waste transfer is increasing as a means to reduce waste hauling costs as landfills become more distant from population centers. Rail haul from transfer stations is becoming more prominent for long-distance hauling.

Processing

- Recent advances in design and sorting technology will benefit MRFs. Small-scale pulping and deinking systems are being considered at some MRFs to increase revenues.

- New MRFs are often built next to other MSW facilities, which is more conducive to co-collection of different waste streams and increases the flexibility for sharing equipment and personnel.

- Mixed waste processing facilities offer high rates of diversion from landfilling, but have experienced problems in marketing sorted recyclables and RDF or compost products. Progress is reported in solving the contamination problems that are largely responsible for difficulties in marketing recyclables and compost from these facilities, but mixed waste processing is largely unproven.

Composting

- Composting is growing rapidly, with yard trimmings representing over 70 percent of compost feedstocks. Separate collection of other biological organic materials from MSW is receiving increased attention as a means to achieve added diversion from landfilling.

- Progress is being made in accessing potentially vast markets for composts in agricultural areas. This may lead to greater co-composting of MSW with manures and wastewater treatment sludges as well.

- Yard trimmings composting, which should continue to be the dominant MSW composting activity, will be conducted mostly in outside windrow operations to minimize costs. The potential for odor problems dictates large buffer zones and a trend toward several smaller operations instead of one large operation.

Combustion

- Current conditions do not favor significant increases in combustion for disposing of MSW. Recent trends suggest that virtually any new MSW combustion capacity will include energy recovery.

Landfilling

- Landfilling will continue as the primary disposal method for MSW within the foreseeable future, although it is more expensive than it was prior to the new federal landfilling standards.

- MSW landfill capacity has increased in the last few years, and a majority of states now have more than 10 years capacity due to new landfills and increased diversion.

- The trend toward very large MSW landfills located at greater distances from population centers will continue. Small landfills are no longer cost competitive and new landfills—particularly larger ones—are difficult to site near densely populated areas.

- Efforts are being made to achieve economies in landfilling costs through innovations in design and operation. For instance, alternative cover materials such as compost and paper mill sludges are being tried as substitutes for (or in combination with) soil.

- Most MSW landfills are expected to continue to employ the "dry cell" approach, which is designed to minimize moisture infiltration into the buried waste and thus halt or greatly slow anaerobic decomposition. The "wet cell" approach is under investigation and development, but is not expected to play a major role in the time frame covered in this report.

Other

- Under certain conditions, landspreading leaves and grass clippings on large open areas—e.g., farm land—can be an effective alternative to composting or landfilling.

- Communities desiring to minimize MSW landfilling without combustion may consider either mixed waste processing or separate collections of recyclable and compostable materials.

- Privatization of MSW management services continues to increase in both the U.S. and Canada. However, the potential for future private sector growth through assumption of services provided by the public sector is more limited than it was a few years ago.

Chapter 2

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Chapter 3

SOLID WASTE MANAGEMENT COSTS

INTRODUCTION

Comparative data on the costs of managing residential municipal solid waste (MSW) by different options are presented in this chapter. The costs of managing MSW from households with individual collection service (i.e., single-family households and, typically, up to four households per building) are emphasized. We believe these costs to be representative of those that would be found in average metropolitan locations in the U.S.

It must be noted that there are wide variations in reported costs for managing solid wastes due to factors that include differences in labor rates, landfill availability, and cost accounting practices. The cost estimates shown in this chapter are, therefore, of greatest value in comparing *cost differences* between management options. These scenarios are based on full cost accounting for the entire MSW system, but are summarized for each component.

The term "full cost accounting" has been used in the last few years to represent a "new" technique for evaluating solid waste management costs, especially with respect to recycling programs operating within the context of a community residential solid waste management system. In fact, the approach we use here is a total MSW system cost approach that is simply engineering economics, which is equivalent to full cost accounting. Some analysts may give a credit to waste diverted from disposal via recycling that is an offset for landfill cost "saved." We have, however, demonstrated that the life of a landfill may be lengthened, but there is still typically a net increased cost to adding a second collection and processing system, e.g., for recycling.

A short discussion on commercial waste costs is also included. However, this discussion excludes detailed cost estimates. Cost comparisons were developed for the following scenarios:

1. ***Landfilling with Baseline Recycling.*** Assumes recovery of household MSW only through drop-off and buy-back centers. Nonrecovered MSW is landfilled. (This scenario is widely used in communities that do not have curbside collection of recyclable materials.)

2. ***ONP and OMG Curbside Recycling.*** Assumes separate curbside collection of old newspapers (ONP) and old magazines (OMG). Non-recovered MSW is landfilled. (This scenario is not often used at the present time.)

3. ***Base Case Curbside Recycling.*** Assumes separate curbside collection of ONP, OMG, and commingled containers. Nonrecovered MSW is landfilled. (This scenario is in wide use at present.)

4. ***Expanded Case Curbside Recycling.*** Includes separate curbside collection of mixed paper along with base case curbside recyclables. Nonrecovered MSW is landfilled. (This scenario is less commonly used at present than the base case scenario, but was selected because it is a way to increase recovery.)

5. ***Expanded Case Curbside Recycling plus Yard Trimmings Composting.*** Includes separate collection of yard trimmings for composting in addition to expanded case curbside recycling. Nonrecovered MSW is landfilled. (This scenario is less commonly used than the base case plus composting, but was selected to represent a way to increase recovery.)

6. ***Waste-to-Energy with Baseline Recycling.*** Same as first scenario except combustion with energy recovery is substituted for landfilling of non-recovered MSW. (This scenario was selected for illustrative purposes; some curbside recovery is commonly used along with waste-to-energy.)

Cost estimates for each of the scenarios are summarized and compared in the following sections. Major factors affecting or "driving" the costs are identified and discussed.

The results of a cost sensitivity analysis on the base case curbside recycling scenario are presented as well. The cost effects of varying recycling participation rates and recyclables market prices are addressed. Twelve different combinations of participation levels and market prices were used in the cost sensitivity analysis. The effects of higher landfill costs when holding participation levels and market prices constant are also presented.

ASSUMPTIONS

Cost estimates for these scenarios were developed using the following assumptions:

- Costs are in 1996 dollars.
- Household MSW generation and composition were estimated based on 1995 data.
- Once per week collection of household MSW at curbside was assumed.
- Costs were developed for household MSW, not including bulky wastes that require separate collection; non-bulky wastes were estimated at 52 pounds per week for an average single-family metropolitan household.
- Cost estimates per household are averages for all households served.

Facilities and equipment necessary with each scenario were assumed to be *new* and were sized for a metropolitan population of 250,000. Other cost factors notwithstanding, household MSW management costs in this size community will be somewhat higher than in communities where facilities are larger.

The landfill and waste-to-energy plant costs are based on a full solid waste service capacity, including multi-family, commercial, and some non-MSW wastes. These costs therefore do not assume only single-family service.

The cost estimates also reflect traditional methods of collecting household MSW. Manual rear-loading packer trucks were assumed for estimating collection of waste to be disposed as well as for separate collection of yard trimmings for composting. Noncompacting multi-compartment vehicles with side-loading lift hoppers were assumed for collection of recyclables. ONP would be collected in one compartment, OMG or OMG plus mixed paper in another, and commingled containers in a third compartment.

COMPARATIVE COSTS OF MSW MANAGEMENT ALTERNATIVES

In this section, costs are presented for each of the scenarios listed above, using the assumptions described. While these costs should not be taken as representative for any particular community, the calculations based on uniform assumptions illustrate the relevance of each cost component.

Landfilling with Baseline Recycling

This scenario (Table 3-1) assumes that all non-bulky household MSW not taken separately to drop-off or buy-back recycling centers is collected and disposed at a licensed landfill. The total cost of collecting, transporting and landfilling this waste was estimated at approximately $94 per ton, or $10 per household per month. Just over 6 percent of the non-bulky household MSW was estimated to be recovered at drop-off and buy-back centers, for which no *net* cost was assumed. Thus, the cost of the disposed MSW allocated to all generated non-bulky household MSW is shown at about $89 per ton.

ONP and OMG Curbside Recycling

This scenario includes separate collection and recovery of ONP and OMG (Table 3-2). Baseline recycling mechanisms (i.e., drop-off and buy-back centers) are assumed for the other recyclables. At a 70 percent household participation level, 60 percent (4.18 pounds per household per week) of the single-family household generated quantity of ONP and OMG was estimated as recovered through curbside recycling.

Over 12 percent of the non-bulky household MSW was estimated to be recovered with this scenario—double that recovered with the landfilling

Table 3-1

METROPOLITAN AREA HOUSEHOLD SOLID WASTE MANAGEMENT COSTS, 1996
LANDFILLING WITH BASELINE RECYCLING (1)(2)

	Household Quantity	Household Cost		
	(Tons/Year)	($/Ton)	($/Year)	($/Month)
Refuse collection & transport	1.269	66.98	85.00	7.08
Refuse landfilling (3)	1.269	27.38	34.75	2.90
Refuse landfilled subtotal	1.269	94.36	119.75	9.98
Drop-off/buy-back recycling	0.082	0	0	0
Total solid waste management costs	1.351	88.61	119.75	9.98

(1) For an average single-family metropolitan household generating 52.0 pounds/week of MSW (not including bulky durable goods).
(2) Assumes collection and disposal of about 48.8 pounds/household/week; recovery of 3.17 pounds/household/week through recyclables drop-off/buy-back programs.
(3) Landfill size assumed for population base of 250,000; estimated at 825 tons/day, 306 days per year of operation.

Source: Franklin Associates, Ltd.

scenario. However, a substantial portion of this recovery (over one-third) would still be through the drop-off/buy-back system.

Estimated household MSW management costs with curbside recycling of ONP and OMG added to refuse collection and landfilling were estimated at about $100, per ton or $11.25 per household per month. The added cost for the limited curbside recycling proposed is, therefore, $1.25 per household per month.

Base Case Curbside Recycling

Separate collection of ONP and OMG, steel and aluminum beverage and food containers, PET containers, HDPE containers (natural and pigmented), and glass bottles and jars is included in this scenario (Table 3-3). A 70 percent household participation level was assumed, which led to an estimated 54 percent recovery of these materials through curbside recycling. With 7.51 pounds per average household per week (10.73 pounds for participating households) recovered through curbside recycling, total recovery of non-bulky household MSW was estimated at just over 17 percent. A small portion of this recovery was through the drop-off/buy-back system.

Household MSW management costs with base case curbside recycling added to refuse collection and landfilling were estimated at about $107 per ton, or $12.05 per household per month. The added cost over that shown for landfilling with baseline recycling is $2.05 per household per month.

Table 3-2

METROPOLITAN AREA HOUSEHOLD SOLID WASTE MANAGEMENT COSTS, 1996 WITH ONP/OMG CURBSIDE RECYCLING (1)(2)

	Household Quantity (Tons/Year)	Household Cost ($/Ton)	Household Cost ($/Year)	Household Cost ($/Month)
Refuse collection & transport	1.186	69.74	82.72	6.89
Refuse landfilling (3)	1.186	27.60	32.74	2.73
Refuse landfilled subtotal	1.186	97.34	115.46	9.62
Drop-off/buy-back recycling	0.057	0.00	0.00	0.00
Curbside recyclables collection	0.109	188.52	20.49	1.71
Curbside recyclables processing (4)	0.109	0.00	0.00	0.00
Curbside recyclables recovery subtotal	0.109	188.52	20.49	1.71
Curbside recyclables revenues (5)	0.109	10.42	1.13	0.09
Net curbside recycling costs	0.109	178.10	19.36	1.61
Total solid waste management costs	1.351	99.75	134.81	11.23

(1) For an average single-family metropolitan household generating 52.0 pounds/week of MSW (not including bulky durable goods).
(2) Assumes collection and disposal of about 45.6 pounds/household/week; recovery of 2.18 pounds/household/week through recyclables drop-off/buy-back programs; and 4.18 pounds/household/week through curbside recycling of ONP and OMG.
(3) Landfill size assumed for population base of 250,000; estimated at 805 tons/day (306 days per year year of operation) from 825 tons/day before curbside recycling.
(4) Existing processing facility assumed. Therefore, cost of processing reflected in recyclables revenues.
(5) Reflects calculated average market prices during the 1990s for the designated recyclables.
Note: Numbers may not add to totals due to rounding.

Source: Franklin Associates, Ltd.

Expanded Case Curbside Recycling

Separate collection of mixed paper in addition to the base case curbside recyclables is included in this scenario (Table 3-4). With 70 percent household participation, an estimated 56 percent of the designated curbside recycling materials would be recovered through curbside collection. This would equate to 11.73 pounds per household per week (16.76 pounds per week for participating households). Total recovery of non-bulky household MSW was estimated at 23.5 percent, including a very small amount from drop-offs and buy-backs.

Household MSW management costs with expanded case curbside recycling added to refuse collection and landfilling were estimated at about $110 per ton or $12.40 per household per month. The added cost over that shown for landfilling with baseline recycling is $2.40 per household per month. In comparison to base case curbside recycling, substantially more recovery is

Table 3-3

METROPOLITAN AREA HOUSEHOLD SOLID WASTE MANAGEMENT COSTS, 1996 WITH BASE CASE CURBSIDE RECYCLING (1)(2)

	Household Quantity (Tons/Year)	Household Cost ($/Ton)	($/Year)	($/Month)
Refuse collection & transport	1.120	72.45	81.17	6.76
Refuse landfilling (3)	1.120	27.76	31.10	2.59
Refuse landfilled subtotal	1.120	100.21	112.27	9.36
Drop-off/buy-back recycling	0.036	0.00	0.00	0.00
Curbside recyclables collection	0.195	139.24	27.19	2.27
Curbside recyclables processing (4)	0.195	86.00	16.79	1.40
Curbside recyclables recovery subtotal	0.195	225.24	43.98	3.67
Curbside recyclables revenues (5)	0.195	61.17	11.94	1.00
Net curbside recycling costs	0.195	164.07	32.04	2.67
Total solid waste management costs	1.351	106.80	144.31	12.03

(1) For an average single-family metropolitan household generating 52.0 pounds/week of MSW (not including bulky durable goods).
(2) Assumes collection and disposal of approximately 43.1 pounds/household/week; recovery of 1.37 pounds/household/week through recyclables drop-off/buy-back programs and 7.51 pounds/household/week through curbside recycling of ONP and OMG, steel and aluminum cans, PET and HDPE containers, and glass bottles and jars.
(3) Landfill size assumed for population base of 250,000; estimated at 790 tons/day (306 days per year of operation) from 825 tons/day before curbside recycling.
(4) Assumes MRF operating at 54 tons/day, 260 days/year.
(5) Reflects calculated average market prices during the 1990s for the designated recyclables. The high prices of 1994–1995 are averaged with the lower prices of 1990–1993 and 1996–1997.
Note: Numbers may not add to totals due to rounding.

Source: Franklin Associates, Ltd.

achieved with this scenario at little added cost under the conditions assumed. *A market for mixed paper is, however, key to the success of this scenario.*

Expanded Case Curbside Recycling plus Yard Trimmings Composting

This scenario assumes separate collection and composting of single-family household yard trimmings in addition to expanded case curbside recycling. No incentives to reduce yard trimmings were assumed, so that virtually all of the yard trimmings (14.22 pounds per household per week) would be separately bagged/bundled and available for separate collection. Thus, total recovery of non-bulky single-family household MSW under this scenario was estimated at nearly 51 percent—over twice that of the expanded case curbside recycling scenario.

Table 3-4

METROPOLITAN AREA HOUSEHOLD SOLID WASTE MANAGEMENT COSTS, 1996 WITH EXPANDED CASE CURBSIDE RECYCLING (1)(2)

	Household Quantity	Household Cost		
	(Tons/Year)	($/Ton)	($/Year)	($/Month)
Refuse collection & transport	1.034	75.45	78.04	6.50
Refuse landfilling (3)	1.034	27.97	28.93	2.41
Refuse landfilled subtotal	1.034	103.42	106.97	8.91
Drop-off/buy-back recycling	0.012	0.00	0.00	0.00
Curbside recyclables collection	0.305	114.47	34.91	2.91
Curbside recyclables processing (4)	0.305	67.00	20.43	1.70
Curbside recyclables recovery subtotal	0.305	181.47	55.34	4.61
Curbside recyclables revenues (5)	0.305	45.19	13.78	1.15
Net curbside recycling costs	0.305	136.28	41.56	3.46
Total solid waste management costs	1.351	109.90	148.53	12.38

(1) For an average single-family metropolitan household generating 52.0 pounds/week of MSW (not including bulky durable goods).
(2) Assumes collection and disposal of approximately 39.8 pounds/household/week; recovery of 0.47 pounds/household/week through recyclables drop-off/buy-back programs and 11.73 pounds/household/week through curbside recycling of ONP, mixed paper, steel and aluminum cans, PET and HDPE containers, and glass bottles and jars.
(3) Landfill size assumed for population base of 250,000; estimated at 770 tons/day (306 days per year of operation) from 825 tons/day before curbside recycling.
(4) Assumes MRF operating at 84 tons/day, 260 days/year.
(5) Reflects calculated average market prices during the 1990s for the designated recyclables.
Note: Numbers may not add to totals due to rounding.

Source: Franklin Associates, Ltd.

Adding separate yard trimmings collection and composting adds approximately $0.85 per month to household costs. The total cost of refuse collection and disposal, curbside recycling, and yard waste composting under this scenario was estimated at nearly $118 per ton, or $13.25 per household per month (Table 3-5).

While an additional $3.25 per household per month is shown to achieve a 51 percent recovery of non-bulky single-family household MSW, *the diversion of yard trimmings appears more cost effective than curbside recycling under the conditions assumed.* However, if only households setting out yard trimmings were charged for this service, less would be collected and diversion would remain about the same. Those choosing not to pay for separate yard trimmings collection would manage them at home, which would be just as effective in diverting the yard trimmings from disposal.

Table 3-5

METROPOLITAN AREA HOUSEHOLD SOLID WASTE MANAGEMENT COSTS, 1996 WITH EXPANDED CASE CURBSIDE RECYCLING AND YARD TRIMMINGS COMPOSTING (1) (2)

	Household Quantity (Tons/Year)	Household Cost ($/Ton)	($/Year)	($/Month)
Refuse collection & transport	0.665	97.25	64.63	5.39
Refuse landfilling (3)	0.665	28.90	19.21	1.60
Refuse landfilled subtotal	0.665	126.15	83.83	6.99
Drop-off/buy-back recycling	0.012	0.00	0.00	0.00
Curbside recyclables collection	0.305	114.47	34.91	2.91
Curbside recyclables processing (4)	0.305	67.00	20.43	1.70
Curbside recyclables recovery subtotal	0.305	181.47	55.34	4.61
Curbside recyclables revenues (5)	0.305	45.19	13.78	1.15
Net curbside recycling costs	0.305	136.28	41.56	3.46
Yard trimmings collection	0.370	63.11	23.33	1.94
Yard trimmings composting (6)	0.370	38.00	14.05	1.17
Yard trimmings recovery subtotal	0.370	101.11	37.38	3.12
Compost revenues (7)	0.370	10.00	3.70	0.31
Net yard trimmings composting costs	0.370	91.11	33.69	2.81
Total solid waste management costs	1.351	117.73	159.08	13.26

(1) For an average single-family metropolitan household generating 52.0 pounds/week of MSW (not including bulky durable goods).

(2) Assumes collection and disposal of approximately 25.6 pounds/household/week; recovery of 0.46 pounds/household/week through recyclables drop-off/buyback programs and 11.73 pounds/household/week through curbside recycling of ONP, mixed paper, steel and aluminum cans, PET and HDPE containers, and glass bottles and jars. Also assumes separate collection of yard trimmings (14.22 pounds/household/week) for composting.

(3) Landfill size assumed for population base of 250,000; estimated at 683 tons/day (306 days per year of operation) from 825 tons/day before curbside recycling and yard trimmings composting.

(4) Assumes MRF operating at 84 tons/day, 260 days/year.

(5) Reflects calculated average market prices during the 1990s for the designated recyclables.

(6) Assumes composting operation at 102 tons/day, 260 days/year.

(7) Assumes 50 percent of incoming yard trimmings as finished compost at $20/ton.

Note: Numbers may not add to totals due to rounding.

Source: Franklin Associates, Ltd.

Yard trimmings composting is the most cost effective *recovery* alternative evaluated. The reasons are: (1) diversion of 27 percent of household MSW, which can be collected cost effectively; (2) relatively low operating costs converting the yard trimmings to compost; and (3) revenue from the sale of finished compost.

Waste-to-Energy with Baseline Recycling

This scenario varies from the first scenario in that MSW collected for disposal would be taken to a waste-to-energy facility instead of a landfill. In view of current prices for energy products, waste combustion—even with energy and steel and iron recovery—appears far more expensive than landfilling. The total cost of household MSW management under this scenario was estimated at about $130 per ton or $14.60 per household per month (Table 3-6). This includes the cost of landfilling the residue/ash from the combustion process.

Table 3-6

METROPOLITAN AREA HOUSEHOLD SOLID WASTE MANAGEMENT COSTS, 1996
WASTE-TO-ENERGY WITH BASE LINE RECYCLING (1)(2)

	Household Quantity (Tons/Year)	Household Cost ($/Ton)	($/Year)	($/Month)
Refuse collection & transport	1.269	66.98	85.00	7.08
Refuse combustion (3)	1.269	94.37	119.76	9.98
Waste-to-energy subtotal	1.269	161.35	204.76	17.06
Energy revenue (4)		-23.80	-30.20	2.52
Recovered ferrous scrap revenue (5)		-0.84	-1.06	0.09
Waste-to-energy revenues		-24.64	-31.27	2.61
Net waste-to-energy costs	1.269	136.71	173.50	14.46
Drop-off/buy-back recycling	0.082	0	0	0
Total solid waste management costs	1.351	128.38	173.50	14.46

(1) For an average single-family metropolitan household generating 52.0 pounds/week of MSW (not including bulky durable goods).
(2) Assumes collection and disposal of about 48.8 pounds/household/week and recovery of 3.17 pounds/household/week through recyclables drop-off/buy-back programs.
(3) Waste-to-energy size assumed for population base of 250,000; capacity need estimated at 700 tons/day; throughput of 462 tons/day.
(4) Assuming revenue from sale of electricity to be $0.04/kwh ($23.80/ton).
(5) Assuming ferrous scrap at 3% of input; 93% recovery rate; revenue of $30/ton (Steel Recycling Institute).

Source: Franklin Associates, Ltd.

COST DRIVERS

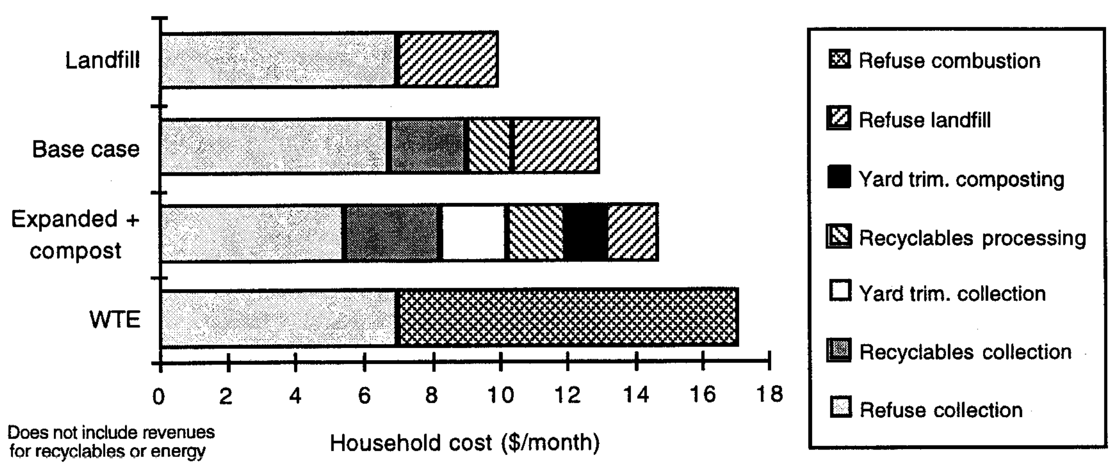
Solid waste management costs are a function of the following cost components or "cost drivers":

- Collection and transportation
- Processing (including recycling and composting)
- Sale of recovered materials/energy
- Disposal.

Collecting and hauling household MSW to a processing or disposal facility is usually the most expensive part of managing this waste stream. Processing occurs when wastes are to be recycled or composted, prepared for fuel use, or perhaps size-reduced prior to disposal. Waste processing may lead to a marketable product from which revenues can be used to reduce or offset costs. Disposal of MSW is typically through landfilling or combustion. Combustion with energy recovery (i.e., waste-to-energy) normally results in a salable energy product such as electricity and recovery of steel and iron from the residue and prior to combustion.

Figure 3-1 illustrates the distribution of costs estimated for management of non-bulky household MSW under four scenarios: landfill with baseline recycling, base case curbside recycling, expanded base case plus yard trimmings composting, and waste-to-energy with baseline recycling. Monthly household cost shown *do not include credit for revenues* from sale of recyclable materials collected or from energy sales and steel and iron recovery at a waste-to-energy facility. The cost components are discussed below.

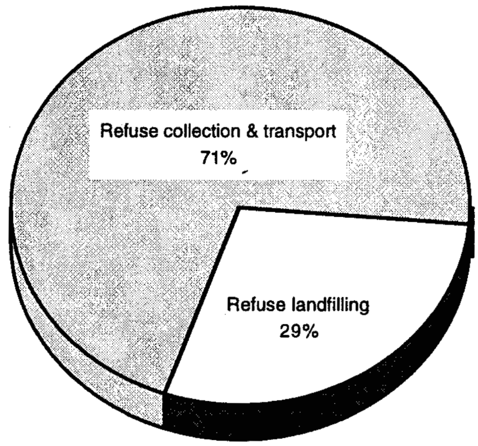
Figure 3-1. Distribution of costs for various single-family household MSW management scenarios



Collection and Transportation

The cost of collecting and transporting household MSW (as derived from Tables 3-1 through 3-6) is clearly the largest cost component in all but the waste-to-energy scenario. Approximately 70 percent of the estimated total costs in each of the landfilling and curbside recovery scenarios is for waste collection and transport. Relative costs for the landfill scenario are shown in Figure 3-2.

Figure 3-2. Distribution of household costs for landfilling with baseline recycling scenario



While collection and transport of refuse to be landfilled is the largest single cost component in each of the landfilling and curbside recovery scenarios, the costs shown for separate collection of recyclables and yard trimmings are also revealing. In both cases, collection and transport of these materials is shown as more expensive than processing the materials (Figures 3-3 and 3-4). Over 60 percent of the curbside recycling costs (exclusive of revenues) is shown for collection and transport; the same holds true for the yard trimmings composting program.

Figure 3-3. Distribution of household costs for Base Case curbside recycling scenario

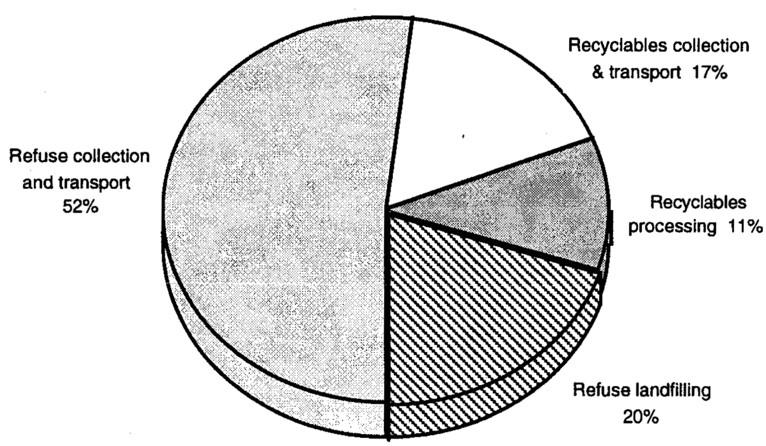
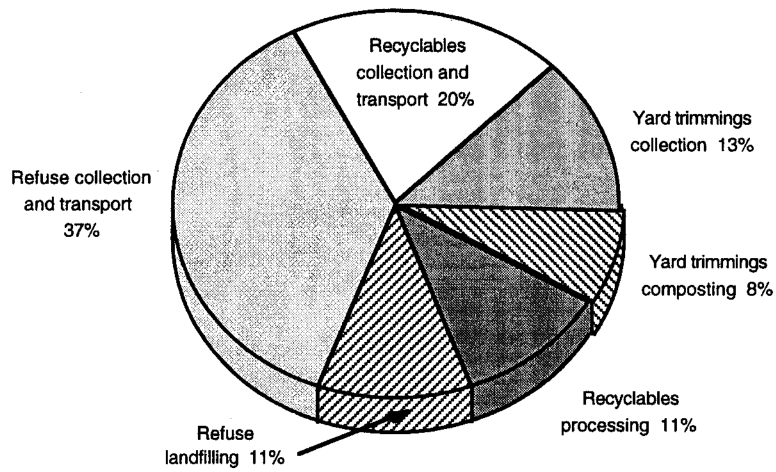


Figure 3-4. Distribution of household costs for Expanded Case curbside recycling and yard trimmings composting scenario



On a per ton basis, separate recyclables collection and transport is more expensive than collection and transport of refuse or yard trimmings. For the base case curbside recycling scenario, the per ton cost of collecting and transporting the designated household recyclables was estimated at almost twice that for refuse—$139 per ton (Table 3-3) versus $67 per ton (Table 3-1).

The time spent collecting household wastes—whether for disposal or recovery—is much greater than that spent transporting the wastes. As such, collection is the major cost driver when examining household collection and transportation costs. The high cost of collecting recyclables in curbside recovery programs is an obvious area to address when seeking to make curbside recycling more cost effective.

Processing

Processing recyclables for sale to an end-user market is usually less expensive than collecting and transporting the materials to the processing facility when traditional collection and processing methods are used (Tables 3-2 through 3-5). However, the ratios shown in Figures 3-3 and 3-4 reflect a materials recovery facility (MRF) designed for a 250,000 population base. A larger or smaller MRF operation could affect the ratio of collection and transportation costs to processing costs. Many larger MRFs in operation today have lower processing costs than estimated for the MRF size assumed here.

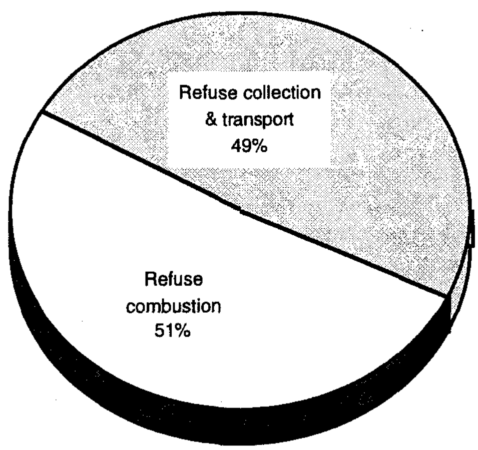
Yard trimmings composting is the lowest cost component shown in Figure 3-4. The per ton cost of yard trimmings composting was estimated to be much lower than that for processing commingled recyclables at a MRF.

Disposal

As illustrated in Figures 3-2, 3-3 and 3-4, the cost of landfilling refuse is typically less than half the cost of collecting and hauling it to the landfill. However, landfilling costs are highly variable depending upon the region of the country and the size of the landfilling operation. In some instances, landfilling costs will exceed collection and transportation costs.

If refuse is disposed through combustion, disposal costs may be higher and the distribution of MSW management costs quite different than when landfilling is used. Figure 3-5 illustrates the percentage breakdown of costs estimated for the waste-to-energy scenario. Whereas estimated collection and transport costs are the same for this scenario as for the landfilling scenario, the waste-to-energy costs are shown to exceed the collection and transport costs.

Figure 3-5. Distribution of household costs for waste-to-energy with baseline recycling scenario



Revenues from Recovered Materials and Energy

Revenues from the sale of recovered recyclables or finished compost were not reflected in Figures 3-3 or 3-4, which show distributions of costs only. The recyclables revenues estimated for the base case curbside recycling scenario—approximately $61 per ton—were enough to offset only 27 percent of the estimated total costs for recyclables recovery. Even with some avoided refuse collection and landfilling costs, the base case curbside recycling scenario was estimated as a higher cost waste management option than landfilling with baseline recycling.

To be cost effective when compared to the landfilling scenario, base case curbside recycling revenues of $187 per ton would be required if costs remained as shown in Table 3-3. For the expanded case curbside recycling scenario, revenues would need to increase from an estimated $45 per ton to $140 per ton. (These figures may be somewhat higher than needed in larger population bases where recyclables processing costs would be expected to be lower than estimated here.) Still, in the absence of ways to cut curbside recycling costs, it is clear that much higher market prices for recyclables are needed if curbside recycling is to compare in costs to landfilling.

Revenues from the sale of energy products is also important to the cost effectiveness of waste-to-energy. Typically, combustion of MSW has proven cost competitive with landfilling only when the cost of energy from fossil fuel sources is quite high and/or the cost of landfilling is high due to hauling distances or landfill tip fees.

COST SENSITIVITY ANALYSIS FOR CURBSIDE RECYCLING

Costs for the base case curbside recycling scenario were examined under varying combinations of recyclables revenues and household participation levels. These factors were used in the cost sensitivity analysis because of their wide variability in curbside recycling programs and the resulting impacts on costs.

The cost sensitivity analysis considered the following potential revenue and household participation conditions with curbside recycling:

1. Recyclables revenues based on high, medium and low market price histories as well as zero market prices.

2. Household participation levels at 90 percent, 70 percent, and 50 percent.

All together, cost estimates were developed for 12 combinations of recyclables revenues and household participation levels in the base case curbside recycling scenario. The combination deemed most likely—medium market prices and a 70 percent household participation level—was discussed previously and compared with the other scenarios in the Scenario Costs section of this chapter.

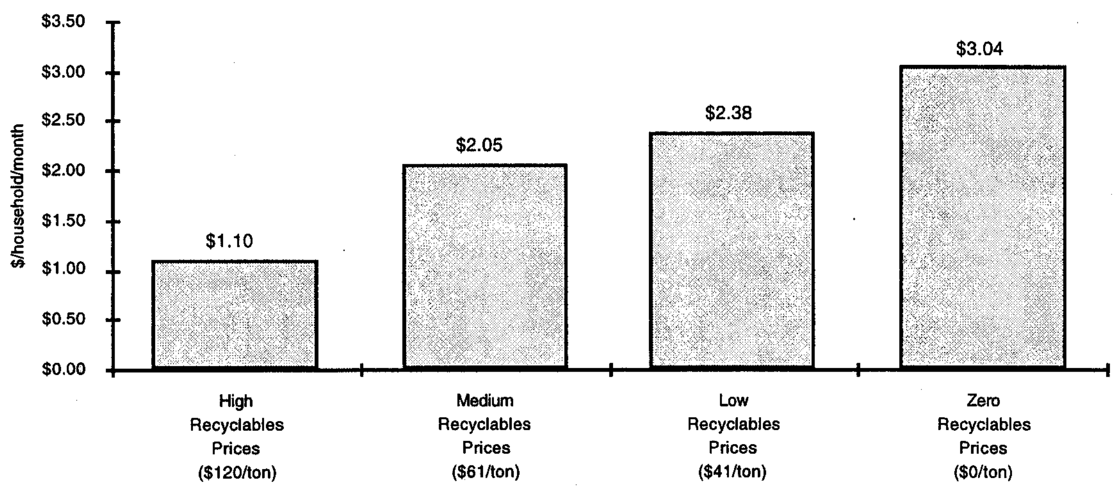
Costs for the base case curbside recycling scenario were also estimated under different landfill costs—another widely varying cost factor. Landfill costs necessary to result in cost effective curbside recycling were determined.

Observations from the cost sensitivity analysis are presented below.

Cost Effects from Varying Recycling Revenues

Changes in the assumed recyclables revenues had a greater effect on the curbside recycling cost estimates than changes in the household participation levels. Estimated increases in single-family household solid waste management costs with base case curbside recycling under varying revenues are shown in Figure 3-6.

Figure 3-6. Household SWM cost increases with base case curbside recycling at varying recyclables revenues



Assumptions and data sources for the analysis shown in Figure 3-6 were:

1. Household participation in curbside recycling was held constant at 70 percent.
2. Results show cost increases over the cost of landfilling with base line recycling for an average single-family household in a 250,000 population metropolitan area.
3. High prices reflect highest 12-month market price periods for each material from 1990 through October 1996 based on prices in ***Pulp & Paper Week*** (paper) and ***Recycling Times*** (containers). Other PET and HDPE prices estimated at 90 percent and 66.7 percent, respectively, of PET soft drink and HDPE natural prices.
4. Medium prices reflect averages calculated from January 1990 through October 1996 based on prices in ***Pulp & Paper Week*** (paper) and ***Recycling Times*** (containers). Other PET and HDPE prices estimated at 90 percent and 66.7 percent, respectively, of PET soft drink and HDPE natural prices.
5. Low prices reflect lowest 12-month market price periods for each material from 1990 through October 1996 based on prices in ***Pulp & Paper Week*** (paper) and ***Recycling Times*** (containers). Other PET and HDPE prices estimated at 90 percent and 66.7 percent, respectively, of PET soft drink and HDPE natural prices.

Cost increases over those estimated for landfilling with baseline drop-off and buy-back recycling are shown to range from $1.10 per household per month to over $3.00 per household per month. The lower cost increase assumes revenues based on the high market price calculations for recyclables ($120 per ton) and the higher cost increase assumes no revenues from the sale of recyclables. As noted in the previous section of this chapter, revenues of $187 per ton would be needed for base case curbside recycling to result in no cost increase for the base case, i.e., the full solid waste management system.

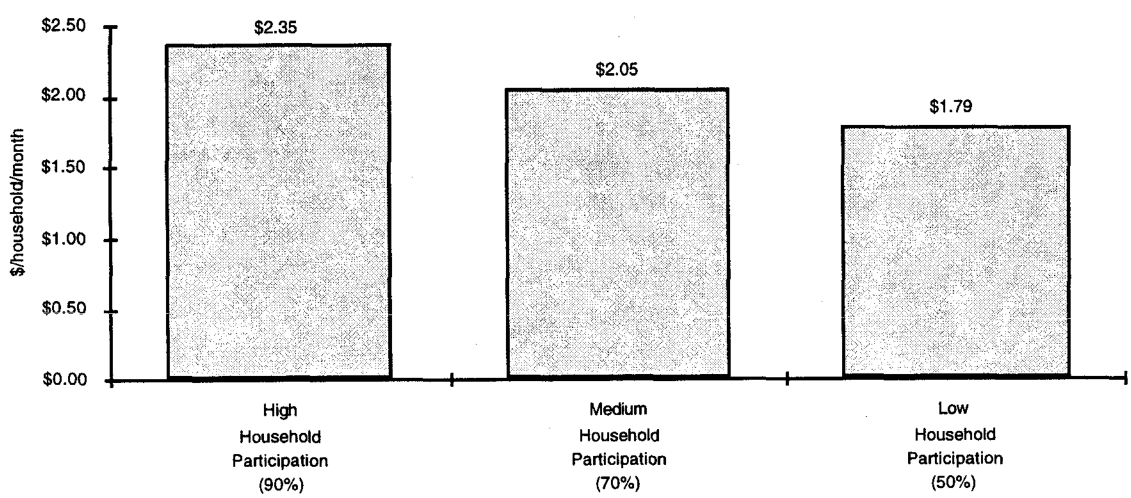
The medium and low market prices calculated for recyclables ($61 and $41 per ton) resulted in little difference in estimated costs for curbside recycling.

Cost Effects from Varying Household Participation Levels

The cost effects from varying household participation in the base case curbside recycling scenario while holding revenues constant are shown in Figure 3-7. This figures also shows estimated cost increases over the cost of landfilling with base line recycling for an average single-family household in a 250,000 population metropolitan area. Recyclables revenues were assumed at $61 per ton average—the medium level estimate calculated from market price histories. Household percentages participating in curbside recycling were based on the range of typical participation levels—a range of 50 percent to 90 percent.

Estimated cost increases over landfilling with baseline recycling range from about $1.80 per household per month at a 50 percent household participation level to $2.35 per month at a 90 percent participation level. Under these assumptions, increased revenues are not enough to offset increased costs of

Figure 3-7. Household SWM cost increases with base case curbside recycling at varying household participation levels



collection. Nevertheless, a community may select this scenario to increase diversion tonnage. There is, however, a danger that contamination of the recovered materials may also increase, leading to lower per ton revenues.

Cost Effects Under Best and Worst Revenue and Participation Level Combinations

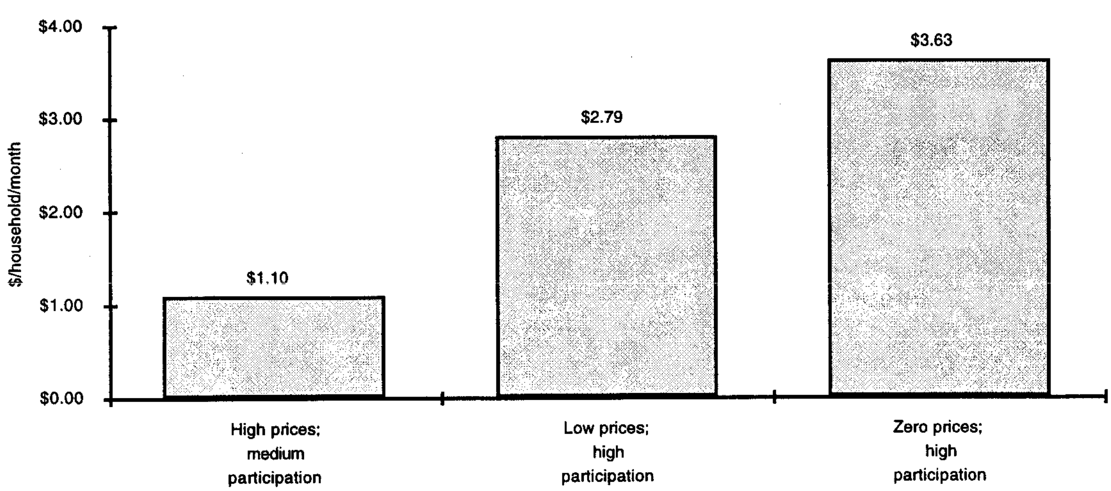
Increases in household costs from base case curbside recycling under the most favorable and unfavorable combinations of recycling revenues and participation levels are shown in Figure 3-8. Assumptions for this analysis were:

1. Results show cost increases over the cost of landfilling with base line recycling for an average single-family household in a 250,000 population metropolitan area.
2. Best conditions were recyclables prices of $120 per ton and household participation of 70 percent.
3. Medium conditions were recyclables prices of $41 per ton and household participation of 90 percent.
4. Worst case conditions were zero recyclables prices and household participation of 90 percent.

Cost increases over landfilling with baseline recycling were estimated to be lowest ($1.10 per household per month) with high recyclables revenues ($120 per ton) and 70 percent household participation. Virtually the same cost increase was estimated at 50 percent and 90 percent participation levels, when the revenue was assumed at $120 per ton.

The largest cost increase (over $3.60 per household per month) is shown with no recycling revenues and household participation at 90 percent. However,

Figure 3-8. Household SWM cost increases with base case curbside recycling under best and worst assumed conditions



with recyclables revenues based on 12-month low market price histories during the 1990s, the household cost increase with curbside recycling was estimated at about $2.80 per month.

Cost Effects from Varying Landfill Costs

Landfilling costs would need to be increased dramatically over those estimated in this analysis to have a very significant impact on the cost effectiveness of curbside recycling. A landfilling cost of $190 per ton would be necessary for the base case curbside recycling scenario to be as cost effective as landfilling with baseline recycling. With landfilling at $100 per ton—nearly four times that estimated—base case curbside recycling would still be expected to increase household costs by $1.10 per household per month.

NON-RESIDENTIAL MSW COSTS

Most non-residential MSW is from wholesale and retail establishments as well as offices and institutional establishments. Costs for collecting and disposing of MSW from these sources vary widely depending upon the quantities collected. Establishments with a single small container—e.g., a two cubic yards "dumpster"—emptied once per week may be charged well over $100 per ton. Conversely, the charge for collecting, hauling, and disposing of waste from a 42 cubic yards roll-off container may be between $35 and $45 per ton.

The cost of collecting non-residential MSW is highly variable and results in the broad range of total costs for management of this waste stream. When large quantities of waste are collected at a single stop, which may be the case at large stores or restaurants with roll-off containers, collection and hauling costs may be less than disposal costs. Conversely, collection and hauling costs experienced at small stores or offices can be as high or higher, on a per ton basis, as those for residential MSW.

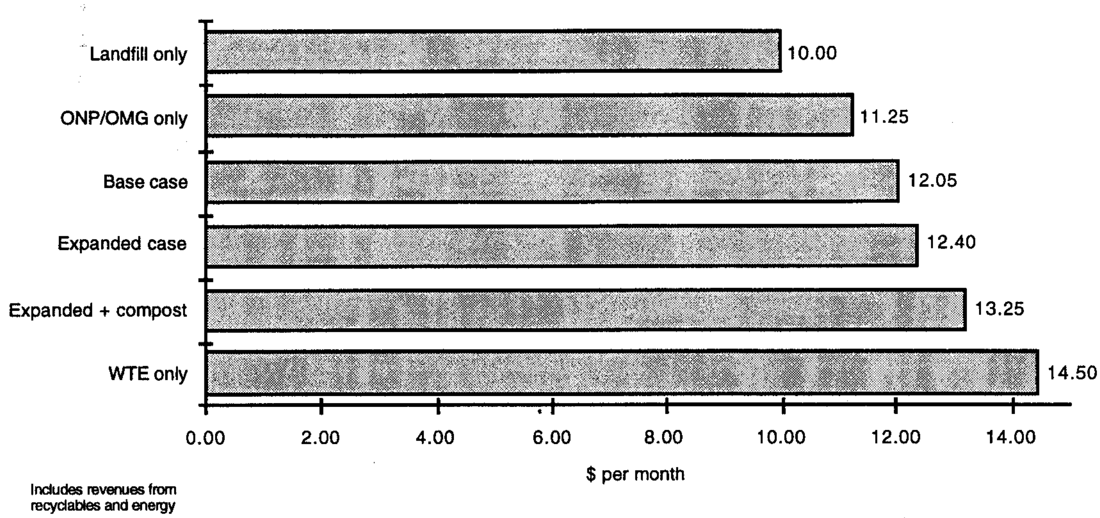
A few solid waste management planning studies have demonstrated differences in costs to manage non-residential MSW depending upon community size. In large metropolitan areas, average per ton costs for collecting and landfilling non-residential MSW is sometimes found to be significantly below the corresponding costs for residential MSW. In smaller communities, the opposite can be true, with non-residential MSW management costs higher than residential MSW costs for MSW that is disposed. Since landfill charges are normally the same for all MSW, the higher non-residential MSW costs in smaller communities can be attributed to the smaller sizes of the businesses. The small businesses lead to less waste collected per stop, resulting in high per ton collection costs.

Nationally, the costs to manage non-residential MSW are less than the costs to manage residential MSW. Total quantities of non-residential MSW are less and the costs per ton to manage these wastes are less in the major population centers. In addition to the non-residential MSW that is disposed, substantial quantities of old corrugated containers (OCC) and office papers from non-residential MSW are recovered for recycling. The recovery of these waste streams reduces costs from what they would otherwise be, thereby lowering non-residential MSW management costs even further. Recovery of residential MSW recyclables, however, often results in higher management costs and increases the spread between the costs of managing residential and non-residential MSW.

SUMMARY OF FINDINGS

Estimated annual costs in a community for each of the six solid waste management scenarios discussed in this chapter are shown in Figure 3-9. The cost estimates are based on a 250,000 population metropolitan area consisting of 71,400 households. These households include single-family units and others that would receive individual waste collection service—normally up to four household units per building.

Figure 3-9. Monthly single-family household net costs for various MSW management scenarios



Total annual costs shown in Figure 3-9 range from $8.6 million for landfilling with baseline drop-off and buy-back recycling (Scenario 1) to about $12.6 million for waste-to-energy with baseline recycling (Scenario 6). These figures correspond to $10 and $14.50 per household per month, respectively.

Costs shown for the curbside recycling scenarios are between those for the landfilling and waste-to-energy scenarios. These cost estimates assume mid-range/best estimates of household recyclables recovery and market prices. Base case curbside recycling (Scenario 3) is shown at about $10.4 million, which translates into $12.05 per household per month. This is $2.05 per month more than landfilling with baseline recycling, but includes curbside collection of ONP, OMG, and food and beverage containers.

Recovery of single-family household MSW was estimated at 17 percent with the base case curbside recycling scenario, 24 percent with expanded case curbside recycling (Scenario 4), and 51 percent with expanded curbside recycling plus yard trimmings composting (Scenario 5). Recovery of yard trimmings is greater than recyclables recovery in Scenario 5 and adds less cost. Yard trimmings collection and composting is the most cost effective recovery option under the conditions assumed. The reason is that the collection and processing costs are closer to the landfilling scenario costs than the costs of recyclables collection and processing.

Collection and transport costs are approximately 70 percent of estimated total solid waste management costs (excluding revenues) for all the scenarios except waste-to-energy. When substituting waste-to-energy for landfilling, collection and transport costs account for about half of total costs.

The per ton cost of collecting and hauling recyclables in the base case curbside recycling scenario was estimated at over twice that for refuse in the landfilling scenario—$139 per ton (Table 3-3) versus $67 per ton (Table 3-1). Since the time spent collecting wastes and recyclables is much greater than the time spent transporting them, collection is the major cost driver. The cost of collecting recyclables in curbside recovery programs is an obvious area to address in efforts to reduce curbside recycling costs.

Net curbside recycling costs were shown to be more sensitive to changes in recyclables market prices than changes in household participation levels. For base case curbside recycling, cost increases over landfilling with baseline recycling were estimated as lowest ($1.10 per household per month) using historically high recyclables prices experienced during the 1990s. This cost increase—for all households served—was estimated to be virtually the same for household participation levels ranging from 50 to 90 percent. A cost increase of $2.80 per month was estimated using low market prices during the 1990s and assuming a 70 percent household participation. (It should be noted that curbside recycling programs in larger communities may sometimes be less expensive and add less to household costs than presented here.)

The costs of managing commercial MSW are highly variable depending on the quantities collected per stop. On a per ton basis, the costs can be more or less than those normally experienced for household MSW. Nationally, the costs to manage non-residential MSW are lower due to less generation and lower per ton costs. However, small communities may experience higher per ton costs because small businesses generate smaller quantities of MSW. The smaller quantities collected per stop result in higher per ton collection costs.

A summary shown in Table 3-7 provides a total dollars perspective to the costs of solid waste management. The costs in dollars and dollars per ton of the various scenarios are based on efficient systems in place. However, some communities have added various configurations of curbside collection with no additional cost. This type of experience, which is not uncommon, reflects one or two local circumstances: very competitive bidding from private haulers and/or modifications of an existing disposal system to shift services to accommodate curbside recycling, e.g., going from twice per week pickup of refuse to once a week collection of refuse and once a week collection of recyclable materials.

Table 3-7

SUMMARY OF NET ANNUAL COSTS FOR MANAGEMENT OF SINGLE-FAMILY RESIDENTIAL MUNICIPAL SOLID WASTE

Scenario	Cost $/ton	$ Million Annual Net Cost	$ Million Incremental Change*	% Increase Over Scenario 1
1. Landfilling with Baseline Recycling	88.61	8.55		
2. ONP and OMG Curbside Recycling	99.75	9.62	1.07	12.6%
3. Base Case Curbside Recycling	106.80	10.30	1.75	20.5%
4. Expanded Case Curbside Recycling	109.90	10.60	2.05	24.0%
5. Expanded Case Curbside Recycling plus Yard Trimmings Composting	117.73	11.36	2.81	32.9%
6. Waste-to-Energy with Baseline Recycling	128.38	12.38	3.84	44.9%

* Calculated at 71,400 single-family homes; 96,461 tons per year.

Source: Franklin Associates, Ltd.

(There are many ways in which existing systems have been made more cost effective as curbside collection goes into place.)

Our principal point here is that the more complex the collection system, the more cost will be incurred, even if this cost increase is offset by changing the basic solid waste service.

SUMMARY OF MSW MANAGEMENT COST SCENARIOS

A summary of estimated single-family household costs for management of non-bulky MSW under each of the six scenarios is found in Table 3-8. Projected recovery of household MSW for recycling/composting under each scenario is shown as well.

The results shown in Table 3-8 indicate that landfilling with baseline drop-off/buy-back recycling is the least expensive single-family household MSW management option—costing about $10 per household per month. The curbside

Table 3-8

SUMMARY OF METROPOLITAN AREA HOUSEHOLD NET SOLID WASTE MANAGEMENT COSTS, 1996 (1)

	Recovery of Household MSW (2)		Net Household Cost (3)	
	(lb/HH/ week)	(% of HH generation)	($/Ton)	($/Month)
1. Landfilling with Baseline Recycling	3.17	6.1	88.60	10.00
2. ONP and OMG Curbside Recycling (4)	6.36	12.2	99.75	11.25
3. Base Case Curbside Recycling (4)	8.88	17.1	106.80	12.05
4. Expanded Case Curbside Recycling (4)	12.20	23.5	109.90	12.40
5. Expanded Case Curbside Recycling plus Yard Trimmings Composting (4)(5)	26.41	50.8	117.75	13.25
6. Waste-to-Energy with Baseline Recycling (6)	3.17	6.1	128.40	14.50

(1) For an average single-family MSA household generating 52.0 pounds/week of MSW (not including bulky durables).
(2) Recovery of household MSW for recycling and composting.
(3) Cost estimates rounded to the nearest five cents.
(4) Curbside recycling estimates reflect calculated average market prices for recyclables during the 1990s and 70 percent household participation.
(5) All household yard trimmings assumed collected for composting in Scenario 5.
(6) Includes revenues from sales of energy and ferrous metals.

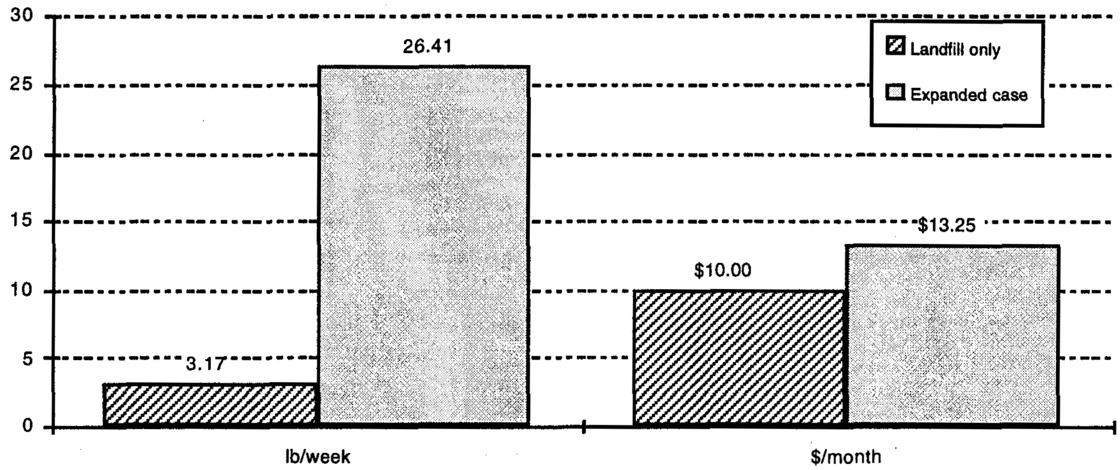
Source: Franklin Associates, Ltd.

recovery options each cost progressively more than the landfilling scenario as more household waste is recovered. Still, the most costly scenario is shown to be that where waste-to-energy combustion with steel and iron recovery is substituted for landfilling.

Revenues from residential curbside recycling programs usually do not cover the program operating costs. However, thousands of communities have come to the decision that the relatively small cost increase provides a service that people are willing to support because they want to be involved in a program they perceive to be beneficial.

When the data in Table 3-8 are viewed from a different perspective, a 33 percent increase in cost yields a greater than 700 percent increase in recovery (Case 1 compared to Case 5). Stated another way, costs would increase by one-third while recovery would increase more than eight-fold. (See Figure 3-10.) Further, 50 percent or more of household discards can be recovered for recycling and composting under an intense, comprehensive, and well managed curbside program.

Figure 3-10. Recovery (lb/week) and household cost ($/month)
Landfill and expanded recycling and composting scenarios



Chapter 3

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Chapter 4

MARKETS FOR RECOVERED MATERIALS

INTRODUCTION

Markets for recovered materials, as addressed in this chapter, are primarily the U.S. manufacturing facilities that make new products out of materials recovered from municipal solid waste (MSW) before disposal. These facilities include paper mills, plastics fabricators, steel mills, aluminum smelters, and glass container plants. Export markets also compete for recovered materials, particularly for paper, but also for other materials. These export markets play a major role in the fluctuations of demand and prices paid for recovered materials.

The collection and processing of recyclables from residential sources has grown very rapidly in the past 7 to 10 years with the advent of curbside collection. On the other hand, new manufacturing facilities to use the recyclables did not spring up nearly as fast. These facilities usually take years to develop—a long period in comparison to the time required for setting up curbside collection programs and materials recovery facilities (MRFs). Thus, there have been some major oversupplies of recovered materials, resulting in low (even negative) prices being paid for the materials collected. These oversupplies and low prices have, however, encouraged the development of new manufacturing facilities, specifically designed to utilize recovered materials. At this time in 1997, the manufacturing capacity to use recovered materials exceeds demand for most materials in most areas of the country.

The capacity to manufacture products from recovered materials has expanded dramatically in the last 10 years. For example, U.S. paper mill utilization of recovered paper has grown from less than 17 million tons in 1985 to over 32 million tons in 1995, a compound growth rate of 7 percent per year. This growth occurred at a time when total paper industry production was growing at a 3 percent overall rate, resulting in an increase in recovered paper utilization in paper mills from 24 percent of production in 1985 to 35 percent of production in 1995. Likewise, there has been a significant growth in the number of plastics recycling facilities.

Although the current capacity to use recovered materials appears to meet the needs in most regions of the country, there are some major problems with market price stability because of small changes in demand for recovered materials. Prices for many of the recovered materials soared to all time highs in the summer of 1995, followed by very low prices in late 1995–early 1996, which have continued for the most part into mid-1997. These huge price swings make planning very difficult and have led to large profits, as well as bankruptcies, all in less than a year.

The main goals of this chapter are to examine these market issues and to investigate the causes of market price swings.

IDENTIFICATION AND DISCUSSION OF FACTORS THAT AFFECT MARKETS

A number of factors affect market demand and the prices paid for recovered materials. Some of these factors are fairly well understood, but because of the number of factors and their complex interactions, market prices continue to cycle up and down in what appears to be a random fashion, and there seems to be little potential for accurate forecasting of either demand or prices. Some of the key drivers that cause market prices to be low or erratic are:

- Inadequate or unreliable demand for end products made totally or partly from recycled materials or products, i.e., demand for finished products is well under the capacity to utilize recovered materials.
- Highly variable demand in export markets.
- Rapid buildup of collection and processing infrastructure in the 1990s, which caused an oversupply of recovered materials for the available end markets (except for a brief one-year period, 1994–1995).
- Increased virgin material manufacturing capacity, causing an oversupply of virgin materials that compete with recycled materials.
- Legislation that either promotes or discourages the use of recovered materials.

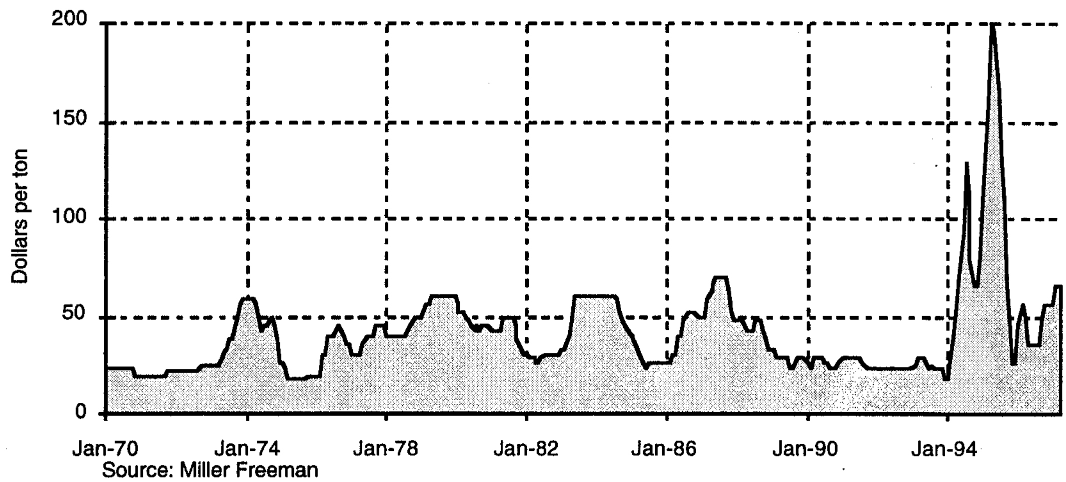
These same factors apply to all recyclables, but specific market conditions are different for each material, discussed separately below.

Recovered Paper

Market History. The dramatic recovered paper price increases of 1994 and 1995 are illustrated in the price history for old corrugated containers (OCC) in Figure 4-1. (OCC is recovered almost exclusively from retail, commercial, and industrial sources.) Average prices that ranged from $20 to $60 per ton since 1970 suddenly exceeded $100 per ton in 1994 and reached $200 per ton in 1995. By late 1995, prices were all the way back to around $20 per ton. OCC prices recovered again in late 1996 and early 1997 to around $50 per ton. In the summer of 1997, OCC prices again exceeded $100 per ton.

Price profiles for other grades of recovered paper are similar to OCC, except that old newspapers, magazines, and mixed paper have shown few signs of recovery. Prices for the higher grades appear to be increasing. Price swings of the

Figure 4-1. Average Chicago end user prices for OCC January 1970 to March 1997 (fob seller's dock)



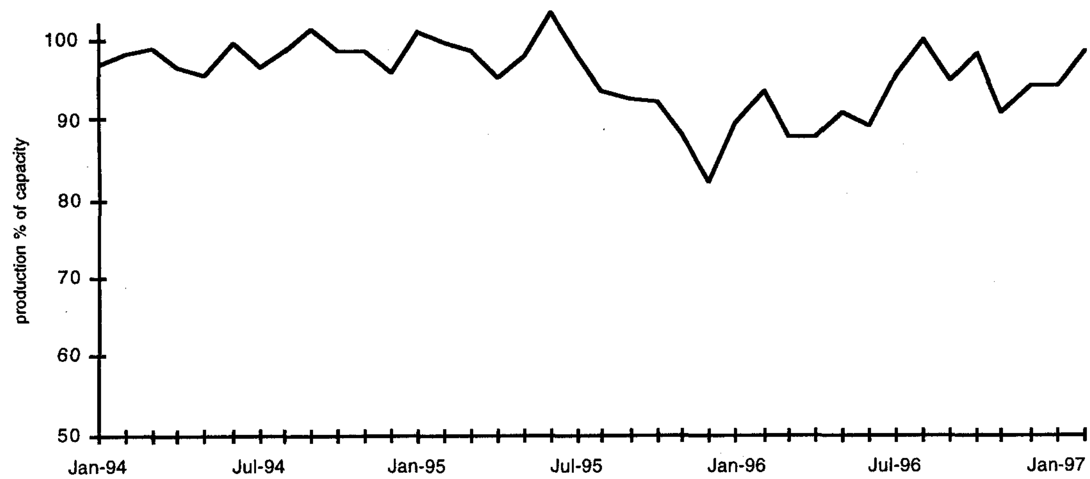
magnitude experienced by the scrap paper industry cannot be explained by any single variable.

The primary drivers affecting the prices of recovered paper are the demand for manufactured paper products that utilize recovered paper and exports overseas. General economic conditions affect the demand for all paper products, including products with recycled content. When the economy expands, demand for products increases, mill operating rates increase, sometimes to maximum capacity, and prices for virgin raw materials and recovered paper rise. As end users reduce their product demand, inventories build up, mill operating rates decline, and prices paid for recovered paper drop. One reason for the inventory buildup is that supply (recovery) does not adjust quickly to incremental changes in demand.

One measure of paper product demand is operating rate, or the percent of total mill capacity that is utilized. Operating rate is determined by comparing mill capacity with mill output. Figures 4-2 and 4-3 show operating rate history for unbleached kraft paperboard and newsprint. The overall capacity to use most grades of recovered paper has been steadily increasing over the last few years—in fact, much faster than virgin fiber capacity.

In late 1994 and early 1995, when the prices for recovered paper reached all-time highs, mill operating rates were at or near 100 percent. In the last half of 1995, mills started taking downtime due to lower order levels. By late 1996, operating rates were in the 90–93 percent range. The selling prices for finished products rise when demand requires high operating rates, e.g., 100 percent. This enables mills to pay higher prices for raw materials. The opposite is also true; when demand falls and mills curtail production in response, finished prices tend

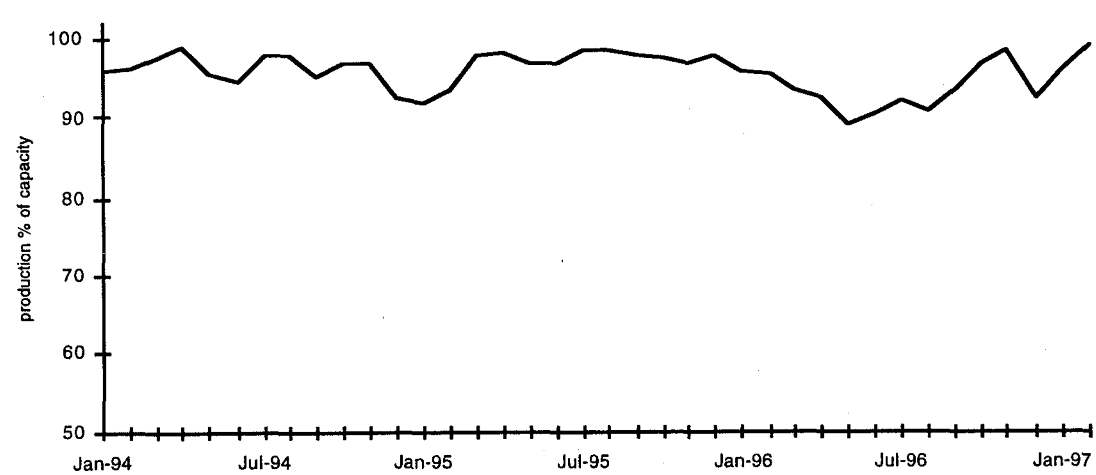
Figure 4-2. Monthly operating rates for unbleached kraft board (normalized to 30 days per month)



to fall and the value of raw materials falls rapidly. In cyclical commodity-like industries, e.g., paper, this is reality.

Although the general condition of the economy is important, it is not the only factor that determines recovered paper demand and prices. Even in a faltering economic cycle, when end users prefer or require that their products contain a certain fraction of recovered material, demand can increase for those specific products, causing prices for recovered paper to rise. Factors that affect the amount of recovered material manufacturers use include consumer demand,

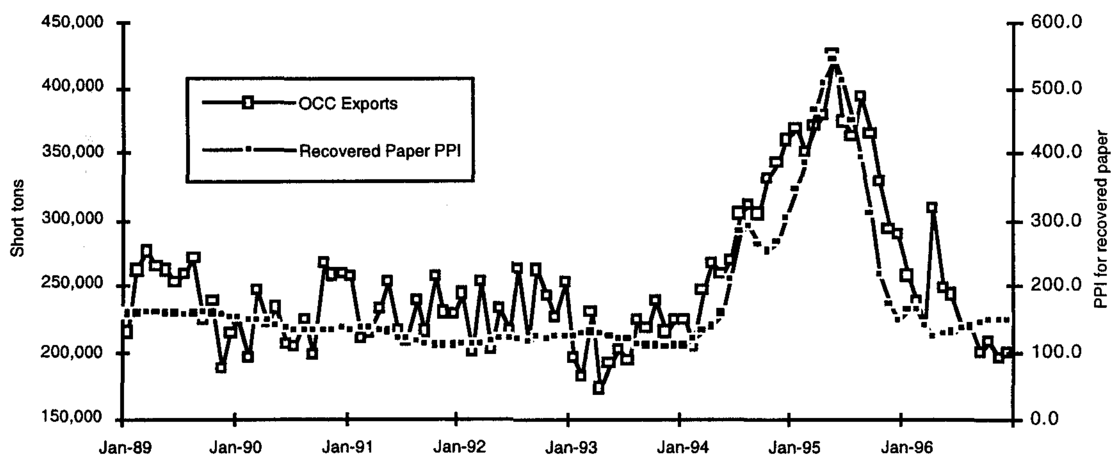
Figure 4-3. Monthly operating rates for North American newsprint (normalized to 30 days per month)



recycled material content legislation, virgin material price and availability, and costs of manufacturing when using recovered material.

When the operating rate of mills is high, which was the case in 1994 and 1995, recovered paper prices are very sensitive also to the demands of the export markets. A relatively small increase in export demand can cause shortages that have the effect of driving prices up very rapidly. Figure 4-4 shows the relationship between tons of OCC exported and the producer price index (PPI) for recovered paper. The PPI is published by the U. S. Department of Labor, Bureau of Labor Statistics (BLS) and is designed to measure average changes in prices received by producers for their output. The information used in calculating the PPI is obtained by BLS through systematic sampling of the manufacturing sectors of the economy. Of course, in a world-wide economy, domestic and export demand tend to track each other.

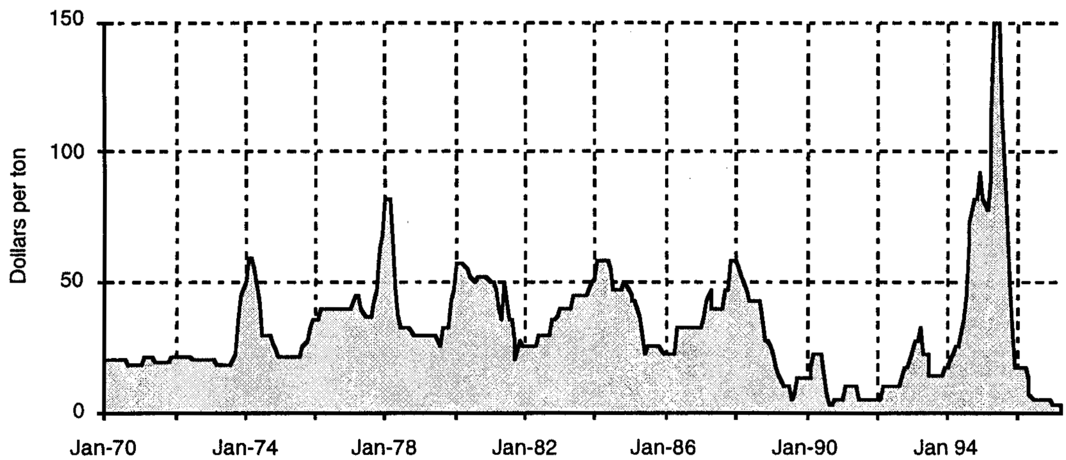
Figure 4-4. Producer Price Index vs. OCC exports



The correlation between quantities exported and market prices is very strong. For the time period 1993 to 1996, when the export demand was highest, prices were high, and when exports were lower, prices were also lower.

The profile for old newspaper (ONP) prices is very similar to OCC, for many of the same reasons (Pulp & Paper 1996). Prices for No. 6 news, shown in Figure 4-5, averaged between $25 and $60 per ton from 1980 through 1988, driven by industry economics. In the late 1980s, because of perceived landfill shortages, curbside collection and drop-off programs sprang up, creating a glut of ONP. The glut then led to legislation designed to increase recycled fiber content in newspapers. The supply/demand equation did not reach equilibrium immediately—not until 1994. When the new mill capacity was in place and export market demands grew, the glut suddenly became a shortage. The result was skyrocketing prices for ONP.

Figure 4-5. Average Chicago end user prices for No. 6 ONP, January 1970 to March 1997 (fob seller's dock)



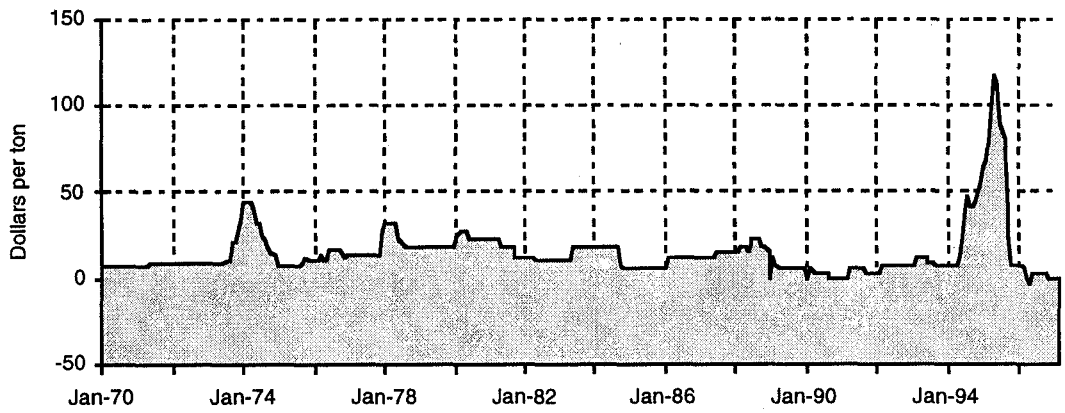
ONP prices dropped very low in late 1995 (Figure 4-5) and stayed near zero through April of 1997, unlike OCC, for which prices headed back up in late 1996 and early 1997. Newsprint mills in Canada and the United States continued having downtimes until early 1997, and export market demands were still down at this writing (Pulp & Paper Week 1997). The selling price for newsprint reflects the cyclical nature of the industry.

The new deinking capacity buildup of the early 1990s included a new deinking technology that can use and has a need for clay found on coated paper, including magazines and catalogs (OMG). Old magazine price profiles tend to follow ONP.

During the period of recovered paper shortages in 1994 and 1995, the lower grades of recovered paper suddenly were in demand as a substitute for more expensive grades. On a percentage basis, the lower grade paper prices show the greatest fluctuations. Mixed paper, which typically had prices around zero to $20 per ton, suddenly could demand over $100 per ton in 1994 and 1995. When prices for the higher grades of recovered paper dropped back to "normal," mixed paper prices went back to zero, or below. As shown in Figure 4-6, there was no sign of a price recovery as of March 1997, and prices are not likely to increase significantly unless there is another shortage of recovered paper.

Sorted postconsumer colored ledger and sorted office paper prices followed a pattern very similar to OCC. Prices varied between $75 and $150 in the 1980s. In 1994, as new deinking systems came on-line, demand increased, causing short term shortages and rapid price increases to $275 to $300 per ton. After bottoming out in the summer of 1996 near $50 per ton, prices moved back up into the $75 to $100 per ton range by the spring of 1997.

Figure 4-6. Average Chicago end user prices for mixed paper, January 1970 to March 1997 (fob seller's dock)



Residential Mixed Paper. Old newspapers (ONP) are the most commonly recovered paper product from residential sources, with old magazines and catalogs (OMG) also often recovered. There are, however, many other recoverable paper products in homes: mail, telephone directories, old corrugated containers (OCC), folding cartons (boxes), and bags and sacks. These residential mixed papers (RMP) can be added to curbside collection programs, and in fact, mixed paper is part of 43 percent of community collection programs, according to an American Forest & Paper Association survey of 14,934 communities (R.W. Beck 1996).*

From a community viewpoint, adding RMP to a curbside collection program can increase diversion, improve participation, and possibly generate more revenue, or at least reduce *cost* per ton. Under the curbside collection scenarios analyzed in detail in Chapter 3, recoverable mixed papers add almost 50 percent to *generation* of typical recyclable materials in residences, and can add over 50 percent to residential curbside *recovery*.

There also are benefits for the paper industry, which provides the markets for recovered mixed papers (usually in uncoated boxboard mills, lightweight linerboard mills, tube and core mills, and roofing mills). These advantages include:

- Mixed papers are low cost compared to other recovered paper grades.
- Mixed papers greatly increase the supply base of recovered paper.

* The survey included both curbside and drop-off collection programs. The average collection rates were: magazines and direct mail (53 percent), telephone books (44 percent), and coated and uncoated paperboard (32 percent).

To meet the paper industry's goal of 50 percent total recovery of paper products in 2000, recovery must go beyond ONP, OMG, OCC, and office papers. Recovery of mixed papers is the obvious choice because other grades will be reaching high levels of recovery. There are, however, some problems associated with marketing recovered RMP:

- Paper mills are reporting contamination problems with mixed papers. Sometimes the mixed papers contaminate other paper grades, especially old newspapers. Also, mixed papers themselves may be contaminated with plastics or other materials. One paper industry expert estimates that contamination from just one source—"stickies"*—costs haulers and handlers $50 per ton for upgrading high grade white papers. In addition, paper mills experience a cost of about $5 per ton for chemical control of stickies (Friberg 1996). The paper industry has invested hundreds of millions of dollars in cleaning equipment for both residential and commercial recovered paper (Hurley 1996).

- Perhaps a more serious problem is fluctuating market demand and the chronically low prices that accompany depressed market demand. When recovered paper prices are high in general, mills are willing to turn to mixed paper as a substitute for other grades, but when overall paper prices are low, mixed papers may bring little or no revenue. In addition, mills will buy the grade most suitable to their operations when the supply is adequate and prices are low or moderate. Consequently, the use of mixed paper will be reduced to "normal" levels in soft markets and will increase when the short term supply of other grades is limited.

- Taking a long term view (longer than five years), the mill use and exports of mixed paper will need to increase as the recovery limits are reached for other grades and when U.S. and worldwide fiber demand increases to the point that mixed paper becomes a fiber source of necessity.

Plastics

Polyethylene Terephthalate (PET). Like recovered paper, scrap PET prices soared to unprecedented heights in late 1994 and 1995. And also like paper, the prices peaked in late 1995 and fell in 1996. By late 1996, though processors were finding markets, prices leveled out below historic values. By mid-1997, prices returned to levels of the early 1990s.

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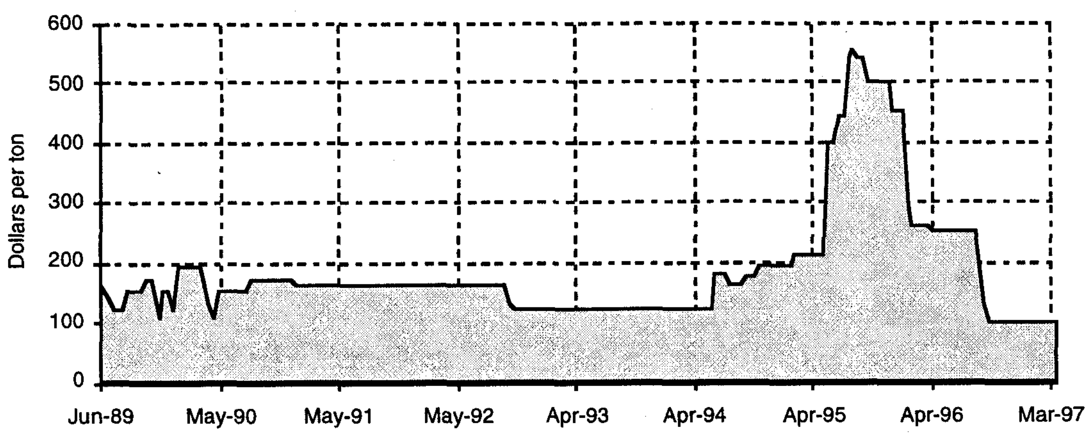
* Stickies are primarily coatings and adhesives on labels, stamps, envelopes, etc., which can cause problems in manufacture of paper from recovered paper.

The capacity to reclaim scrap PET is not an issue. A 1995 survey of U.S. PET reclaimers indicated a total installed annual washing capacity for clean flake of almost one billion pounds in 27 plants operating in 18 states (Resource Recycling 1995). In 1995, 645 million pounds of post-consumer PET were processed. Of this, about 43 percent went into the manufacture of fibers, 24 percent was exported, 7 percent was used to make food bottles, 9 percent went into non-food bottles, and 17 percent was used for all other purposes (Modern Plastics 1996).

Scrap PET prices have traditionally been relatively stable compared to other recovered materials. Prices for baled PET bottles in the period 1992 to November 1994 averaged between 7 and 10 cents per pound, f.o.b. shipper (Resource Recycling 1995). In the six months starting at the end of 1994, prices for used PET bottles headed upward in leaps of 4 to 5 cents per pound, until by late spring baled PET bottles were sold delivered for over 30 cents per pound (40 cents on the west coast). The history of average end user prices for clear PET in the east central region is shown in Figure 4-7.

Figure 4-7. Average end user market prices for clear PET East Central Region June 1989 to March 1997 (delivered)



In 1996, the scrap PET market took a nose dive. By late summer, the price for used bottles had fallen from more than 20 cents per pound to 5 cents per pound, where it remained through 1996. Multi-tier pricing, where price is dependent on material quality and end use, came into existence. That along with contract buying resulted in prices ranging from the historic norms to lower. In the fall of 1997, scrap PET prices were back in the "normal" range of 8 to 9 cents per pound ($160 to $180 per ton).

Figure 4-8 shows U.S. consumption of virgin PET in the manufacture of blow molded bottles from 1984 to 1996. The graph shows the rapid growth in 1994 through 1996. In the scramble to expand, capacity to produce PET grew faster than demand, resulting in an oversupply of virgin resin in the short term.

Figure 4-8. U.S. virgin PET pattern of consumption (Excludes postconsumer recyclate)

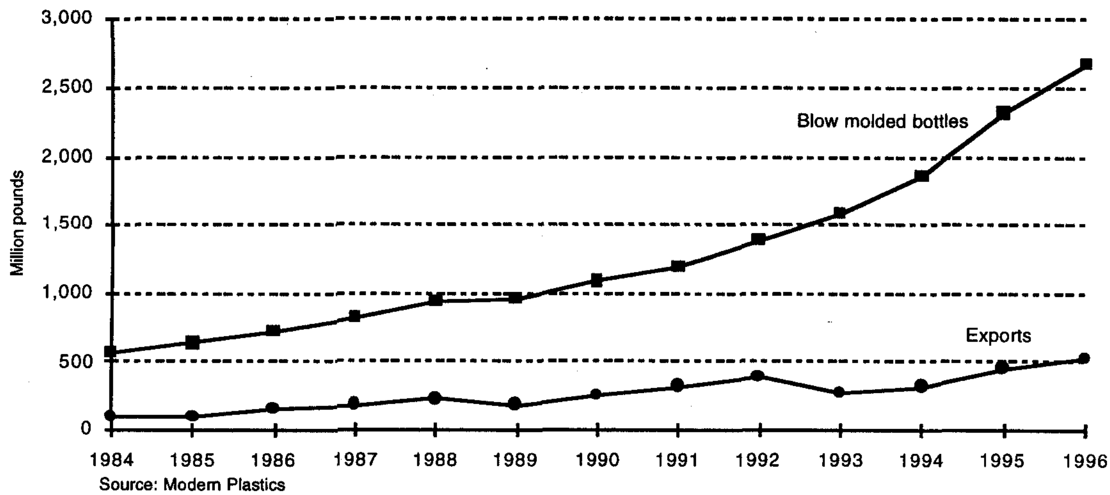
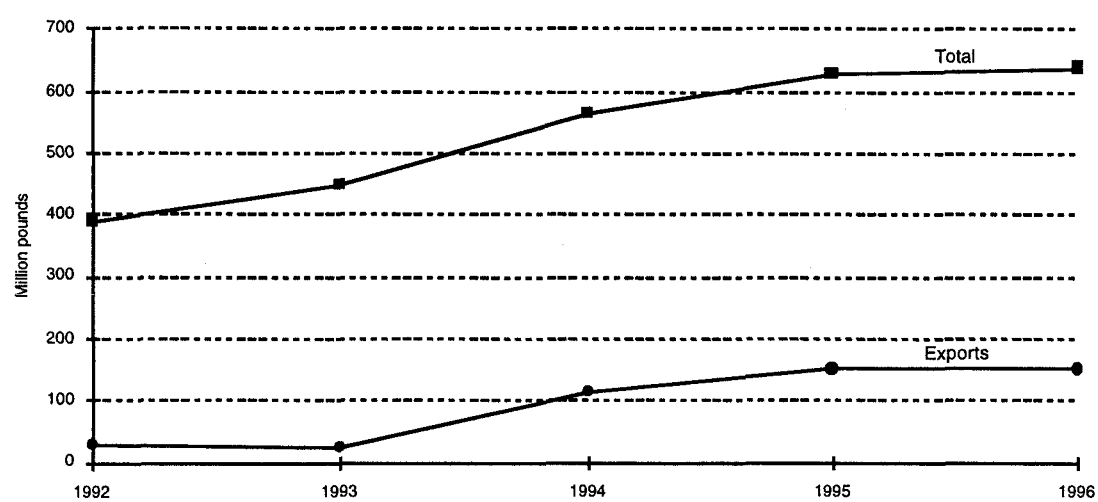


Figure 4-9 shows the consumption pattern for postconsumer PET from 1992 to 1996, showing a "leveling off' in 1996.

In summary, market conditions for postconsumer PET are in many ways similar to the markets for recovered paper, and demand for end products made from recovered material is relatively stable. Said another way, the market went through an entire business cycle in a two-year period, and is stable again at this writing.

Two principal factors affect recovered PET in the marketplace:

Figure 4-9. Postconsumer PET pattern of consumption, 1992 to 1996



- First, new high value applications for recovered PET need to be developed. The technologies that have been under development for using recovered PET in food containers have been determined to be cost competitive at large scale. Along with this development, efforts need to be expended to reduce collection and processing costs, to more effectively compete with virgin material for existing markets.

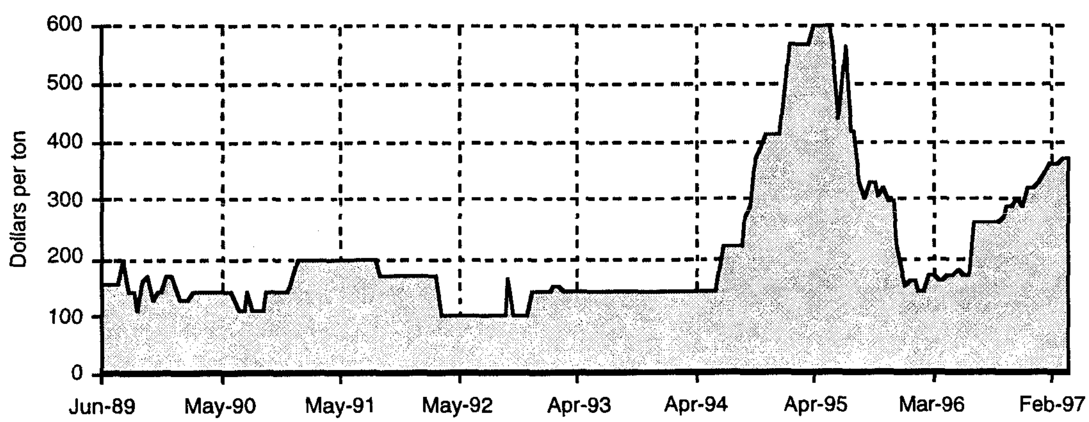
- Second, collecting the very successful 20-ounce soft drink containers, which are often discarded away from the home, may be a significant issue to resolve. The existing collection infrastructure does not readily capture the proliferating smaller PET containers because they often are not discarded at residences. New capture methods are needed. The National Association for Plastic Container Recovery (NAPCOR) is currently using prototype bins to test recovery of single-serve PET bottles from commercial and institutional facilities.

Finally, PET recovery and markets will continue to be an important part of recycling activity, especially from residential sources.

High Density Polyethylene (HDPE) Containers. High density polyethylene containers (for milk, water, and juice) are part of most curbside collection programs. Other containers made of pigmented HDPE (e.g., detergent bottles) are also collected in many programs. Markets for recovered HDPE include the manufacture of blow molded containers, plastic pipes, leaf bags, and plastic lumber.

Like PET, HDPE prices skyrocketed in 1994 and 1995, only to fall back by early 1996. Figure 4-10 shows how the average end user prices in the east central region have varied since June of 1989. (The east central region was chosen as

Figure 4-10. Average end user market prices for natural HDPE, East Central Region, June 1989 to March 1997 (delivered)



representative of the U.S. for price histories.) The shortage of virgin HDPE and the prospect of recycled-content legislation have been given as explanations for the high prices in 1995 (Resource Recycling 1996). Prices went as high as 32 cents per pound in some areas. The price spike was short-lived; prices dropped to 5 to 7 cents, then recovered to 18 to 22 cents per pound in mid-1996, and were back to an average of 20 to 25 cents per pound in the fall of 1997 ($400 to $500 per ton).

The market outlook for HDPE appears bright at this time. There is not an oversupply of virgin HDPE to compete with recovered material. The prices for HDPE began moving up in July 1996, when several smaller consumers came into the market, bidding up the market by a few cents per pound (Container Recycling Report July 1996). A major recycler matched the prices, causing other major consumers to match those prices in other regions of the country. It's a matter of supply and demand, and the demand is high enough to keep the prices up.

Steel Cans and Appliances

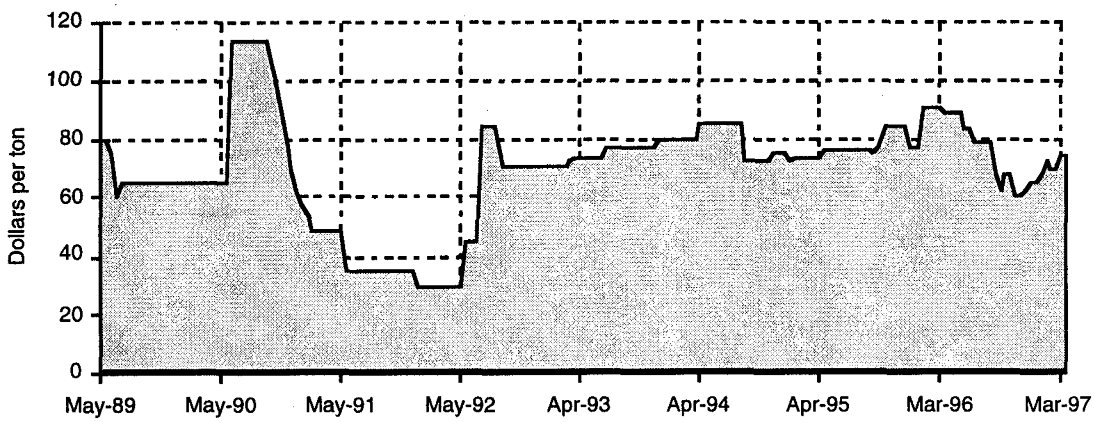
Steel cans and major appliances are the main sources of steel and iron recovered from MSW. Steel cans, a very common component of household waste, are collected via drop-off and curbside collection programs and from the ash of MSW combustion plants. Very few steel cans are collected in buy-back facilities. Used appliances are managed by a combination of MSW solid waste management systems, retail outlets, and private haulers. Then they are processed at automobile shredding or other scrap processing operations. Steel has the advantage of being easily separated from other materials using magnets.

The steel industry has been very actively promoting the collection and processing of steel cans, as well as major appliances, and assuring there would be markets available for the scrap steel. Four scrap executives made predictions at a steel industry forum last summer that prices will continue to rise at least for the next year or two, and likely longer, due to a steel and iron scrap shortage (Scrap 1996).

Steel can scrap prices have remained relatively stable for the last five years, as shown in Figure 4-11. Average end user prices are shown for the east central region. Demand for steel scrap exceeds supply, making for stable or rising prices. Prices for scrap steel are higher in the Chicago–Philadelphia steel belt than in most other parts of the country. West of the Mississippi, prices are about half of the top eastern prices (Bottle/Can Recycling Update 1996).

Prices for scrap steel are expected to remain strong as a number of new electric arc furnaces come on line. Twelve to 15 million tons of new steel production capacity is expected to come on-line in North America within the next 12 months, and these producers will rely heavily on scrap for a substantial portion of their feedstock (Scrap 1996). The new demand, along with existing

Figure 4-11. Average end user market prices for baled steel cans, East Central Region, May 1989 to March 1997 (delivered)



consumption and exports, should make the scrap steel market active through 2000.

Aluminum Cans

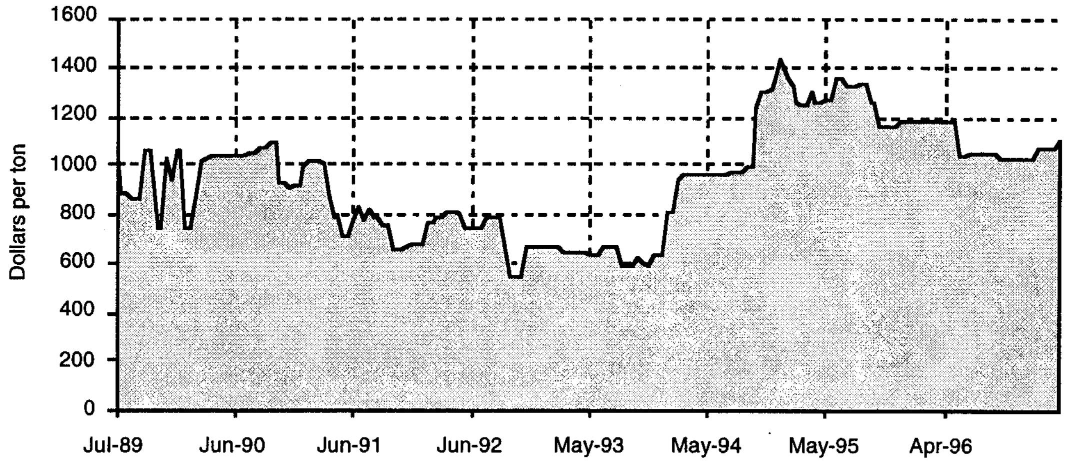
Aluminum cans make up a relatively small part of MSW (less than one percent of total), and they are a small part of the materials commonly recovered from households. However, their value is high compared to the other recovered packaging materials. The aluminum industry has supported recovery programs because of the cost advantages in using recovered cans for the production of can sheet and other products.

The capacity is in place to use all aluminum cans that can be collected from MSW, though not necessarily into their highest recycled value usage—can sheet. Most recovered used beverage cans (UBCs) are consumed in the manufacture of new can body stock in closed loop recycling. However, primary aluminum is also used in the can body stock to maintain quality standards and reliability. Other users of UBCs include foundries that produce castings for automobiles, motors, and hardware. Exports made up less than one percent of the market for UBCs in 1996.

In the 1960s and 1970s, when most aluminum cans were collected in buy-back programs, the amount recovered could be controlled to a certain extent by the scrap prices offered. However, the supply of material from curbside and deposit law collection programs is steadier and less dependent on the prices offered. As more cans are collected in a steady stream, it is thought that can sheet manufacturers will adjust the amount of cans they use accordingly.

Like paper and plastics, the market for aluminum (UBCs) experienced high prices in late 1994 and early 1995, as shown in Figure 4-12. Prices began

Figure 4-12. Average end user market prices for aluminum cans East Central Region, July 1989 to March 1997 (delivered)



falling in mid-1995, but not precipitously, like paper and plastics. The reason for the price decline is thought to be the result of large can sheet and container inventories that have the effect of reducing primary aluminum prices and also UBC prices. However, the market price achieved some stability in 1997. Because aluminum cans are the most valuable of the commonly recovered materials in MSW, they will continue to be recovered at a relatively high rate into the future.

Glass Containers

Glass containers are the second most prevalent product by weight in residential waste (old newspapers are first). Glass containers are used to package soft drinks, beer, other beverages, food products, cosmetics, and other products. However, glass beverage bottles for carbonated soft drinks are continuing to vanish from the marketplace.

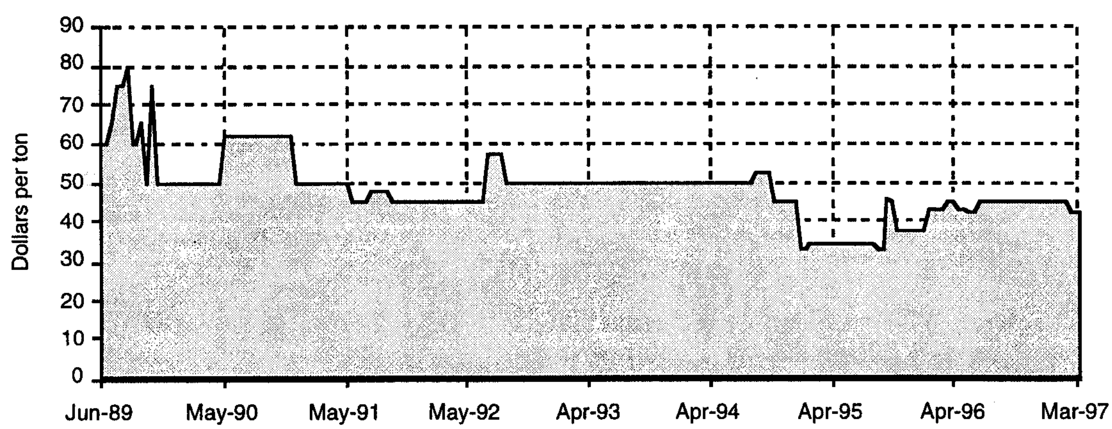
The primary market for glass cullet is 62 glass container plants, which are clustered in several regions of the country. The number of glass container plants has dropped from 127 in 1978. Capacity to process glass cullet is not a problem because per plant production has basically doubled since 1978. Transportation is, however, a significant cost item, particularly for glass recovered in the Rocky Mountain region. There are some alternative markets for recovered glass containers, e.g., highway construction materials and fiberglass.

Glass did not experience the dramatic 1995 increase in prices as did most of the other recovered materials. Rather there is an obvious drop in prices in early 1995. Two glass plant closures in California kept glass prices on the west coast down (Waste Age 1995). Also in early 1995, a large user in Colorado started buying only color-sorted glass because of the impurities that were expensive and time-consuming to remove. Prices came back up in 1996 and appear to have stabilized about $45 per ton.

Glass that is clean and color sorted is marketable in the United States. Average market prices for clear cullet in the east central region for June 1989 to March 1997 are shown in Figure 4-13. Some of the glass that is not considered readily recyclable in the United States, e.g., green and mixed color glass, can be used for markets abroad (Waste News 1996).

Recovery of clean, color sorted glass is an issue in communities that collect commingled containers. Once the glass containers become broken, they are costly to color sort, and mixed colors are not acceptable to most glass markets.

Figure 4-13. Average end user market prices for clear glass, East Central Region, June 1989 to March 1997 (delivered)



Compost

Recovery of yard trimmings and other organic materials from MSW offers great potential for waste diversion. In 1995, about 20 percent (or 9 million tons) of yard trimmings and about 4 percent (570,000 tons) of food waste were recovered for composting. Compost is a soil amendment that improves many soil properties, such as porosity, structural and thermal stability, water retention, resistance to wind and water erosion, and tillage.

The primary markets for compost are agriculture, landscapers, nurseries, public agencies (highways, parks, etc.), and residential landscaping and gardening. Since these uses apply in all parts of the country, compost is usually marketed close to the point of generation. Shipping costs may exceed the value of the compost if the market is more than about 50 miles from a composting operation.

Most separated organics are generated in urban areas. However, the largest market potential is agricultural. Much work is underway in developing agricultural compost markets, particularly in California (BioCycle 1997).

There appears to be adequate market capacity to handle additional quantities of recovered yard trimmings. However, the market value of compost is relatively low, so the end user typically pays just the transportation costs for delivering the finished product, except in the northeast and on the west coast, where end users may pay from $2 to $27 per cubic yard, depending on product quality, competition, and customer type (BioCycle 1996). The costs for composting are approximately equal to landfill costs. Therefore, the economic incentive for composting in most parts of the country consists of saving landfill space. Compost that does not meet commercial standards of quality is often used as landfill cover material, thus replacing soil, the most common cover material.

Overall, the markets and value of compost are in a growth mode. The Composting Council has released several new publications and a compost video. Education has helped reduce product-related stigmas, and experience has shown compost to be a valuable and versatile product.

MARKET CAPACITY AND OUTLOOK

General Observations

The cyclical behavior of market prices reflects changes (sometimes minor) in actual demand for recovered materials. During the period mid-1994 through mid-1995, there was a state of euphoria in the recovered materials industry due to the high prices being paid for recovered materials. Predictions were common that this situation would not change in the foreseeable future. At the same time, there was strong bidding for materials from the users of recovered materials to keep operations going and to fill orders for products with recycled content. But, the historically high prices could not be sustained, and the drop was as precipitous as the price increases.

Through 1996 and early 1997, market prices were depressed for most materials. There was a "shake out" in progress, with the general feeling that the depressed markets will continue into the foreseeable future. Recovery of materials in 1996 was flat to up in quantity, however, and did not mirror the dramatic price decline. The point is that prices do not tell the full story.

We are in a transition phase and a major adjustment in recovery of materials. It would appear, however, that longer term recovery based on slowly increasing demand will prevail. (This assumes a continued growth in demand for manufactured goods.) More supply/demand cycles will occur with changing economic business cycles. The situation in each material category is summarized below.

Paper and Paperboard

The key to total tonnage recovery and percent recovery from MSW depends heavily on paper and paperboard. Paper and paperboard recovery is about 70 percent of total materials recovered for recycling (58 percent when composting is included). Over the period 1995 to 2010, we have projected postconsumer paper recovery to increase by more than 16 million tons, to 49 million tons. The situation is this:

- Total domestic mill capacity to utilize recovered paper is projected to increase each year between 1995 and 2000 (AF&PA 1996).

- There is, however, significant unused capacity in deinked market pulp for printing and writing paper (office paper and other similar grades). Thus, market demand for deinked pulp is a key to increased requirements for office paper recovery.

- Exports of paper is the principal "wild card." From 1994 to 1995 exports increased from 7.7 million tons to 10.4 million tons. In 1996 exports were 7.2 million tons, down 31 percent over 1995. In the early months of 1997, exports were down another 20 percent over 1996. Thus, exports of recovered paper have become the key variable, since domestic mill use is still rising.

With domestic mill demand for recovered materials still increasing except for deink pulp grades, major changes will only take place when exports revive.

PET

We have projected recovery of PET containers to rise from 0.31 million tons in 1995 to over 0.5 million tons in 2010. At present, the very popular 20-ounce PET bottles do not get into residential curbside programs because they are not usually purchased for use in the home. Also, a significant quantity of PET is recovered in states that have deposit laws in place. Stabilization of recovery of PET took place in the second quarter of 1997. Longer term, we expect PET recovery to increase.

HDPE

HDPE bottle recovery has been strong, as have markets for HDPE. We have projected recovery increasing from 0.32 million tons in 1995 to about 0.4 million tons in 2010. Uses of recycled HDPE appear to have become stable, although a significant increase in the capacity to produce virgin resin could lead to temporary changes in recovery of HDPE. At present, this appears to be unlikely.

Steel Cans and Appliances

Although scrap steel markets have been somewhat cyclical, the recovery of steel from appliances, cans, and other steel products in MSW continues to climb. In effect, the steel industry can absorb any quantity of steel recovered from MSW because the MSW-derived steel is a small part of total scrap steel required by the industry.

We have projected steel recovery from MSW to increase from 4.2 million tons in 1995 to over 6 million tons in 2010. The issue is whether communities and private sector firms will sustain and increase recovery of steel. Also, as shown earlier, steel scrap prices have been more stable than prices for paper or PET.

Aluminum Cans

We have projected recovery of aluminum cans from MSW to increase from 1.0 million tons in 1995 to 1.5 million tons in 2010. Recovery of aluminum cans did, however, fall between 1994 and 1995, both in tonnage and in percentage. Our projections therefore require some renewed efforts at aluminum can recovery.

We believe that there will be sufficient capacity to use all recovered aluminum cans, although some might go to end users other than can sheet makers, e.g., foundries or exports.

Glass Containers

There is sufficient glass container capacity to take all color-sorted recovered glass containers. Marketing recovered glass does, however, become a problem when transportation distances are great, e.g., in the Rocky Mountain states. Since production of glass containers has been "flat" to down for the past several years, we are projecting that recovery will continue to increase, but not rapidly.

Market prices for recovered glass have been relatively stable compared to other materials, and there seems to be no reason to project any dramatic changes. We are projecting recovery of glass bottles and jars to increase from 3.1 million tons in 1995 to about 5 million tons in 2010.

Compost

The market outlook for yard trimmings compost appears to be stable. That is, markets are almost always local and only in relatively few locations do prices received exceed transportation costs. Community decisions to produce compost generally are driven by diversion goals rather than market prices.

SUMMARY AND CONCLUSIONS

The following general observations can be made about markets for recovered materials:

- In the early 1990s, capacity to utilize recovered materials was not always adequate, and recovery was ahead of capacity and demand.

- After going through a one-year period of strongly increased demand (1994–1995), there was a dramatic change in markets in 1996. By the last quarter of 1997, most market demand had stabilized.

- The outlook for most recovered materials is that demand will continue to grow over the long term. However, the increase in demand will be relatively modest and from time to time, business cycles will lead to significant short term increases in demand, followed by equally significant declines.

Chapter 4

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Chapter 5

OUTLOOK FOR THE TWENTY-FIRST CENTURY

INTRODUCTION

As this report is written (late 1997), the next century and the next millennium are close at hand. Municipal solid waste (MSW) management as we know it is a relatively recent development, starting with early designs of sanitary landfills about 30 years ago, moving into construction of modern waste-to-energy plants with emission controls in the late 1970s, and emphasizing recycling and composting in the latter part of the 1980s, along with Resource Conservation and Recovery Act (RCRA) regulations on landfills. At the present time, all of these management techniques are being practiced, and there is also renewed interest in reducing the amount of waste generated at the source and diverting it from disposal. In fact, there seems to be a slight tilt towards diversion from landfilling as a strategic objective for a number of communities and states.

Recent years have seen many changes in the solid waste management industry. Large national solid waste management companies are in a period of restructuring and realignment, and some relatively new regional and national solid waste management firms have emerged and are purchasing existing companies. As one analyst recently observed (Holman 1997), the solid waste business is dividing into two segments: front-end consumer services such as collection, and back-end processing and disposal. Disposal and processing require large investments of capital, and thus are more difficult businesses to enter. The restructuring should bring some new efficiencies to municipal solid waste management, but there will be some readjustments while this is occurring.

This chapter looks ahead to the year 2010, basing projections not just on what has already happened, but on reasonable expectations for the next decade.

PROJECTIONS AND OUTLOOK FOR THE FUTURE

This section first introduces the concept of diversion from landfilling, followed by projections of generation of municipal solid waste to the year 2010. Then, projections and outlook for the various management alternatives—recovery for recycling and composting, combustion, and landfilling—are presented and discussed.

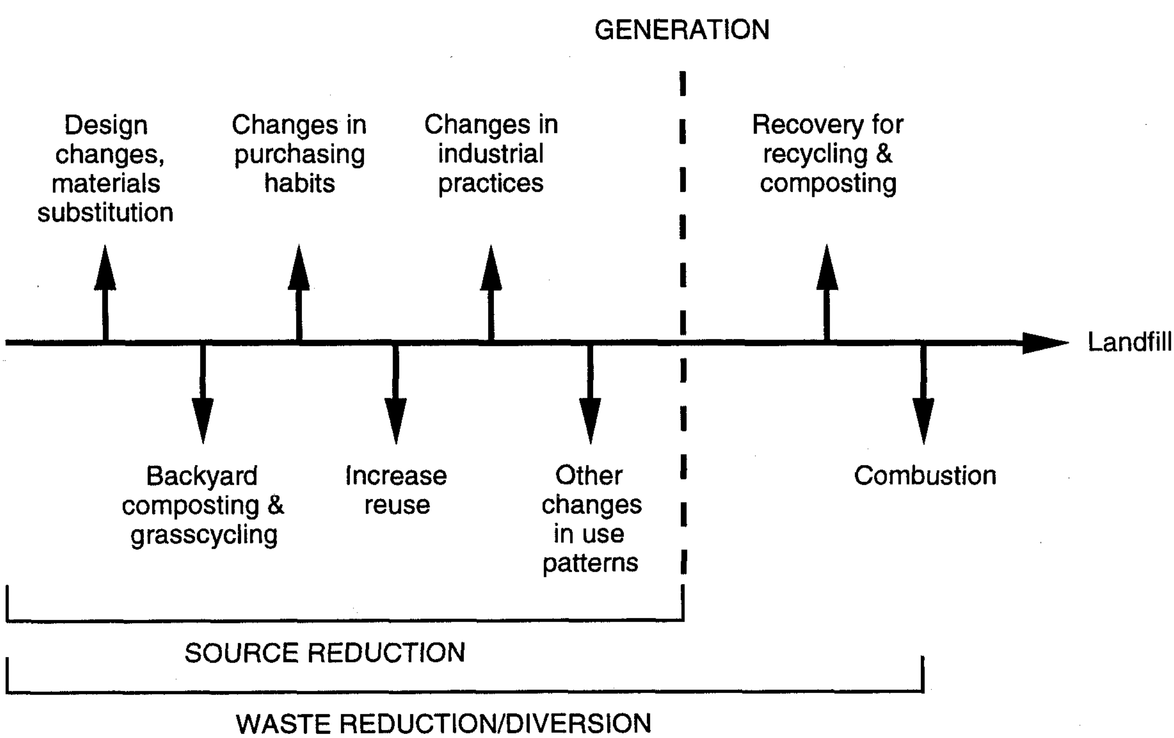
Diversion from Landfilling

The concept of "source reduction," has long been at the top of the hierarchy for EPA and other entities such as state agencies. There now seems to be an accelerating interest in pollution prevention, waste reduction, waste diversion, or source reduction, to cite some of the terms in use. It may be that much of the interest is being driven by economic considerations, especially in the private sector. By conserving materials and reducing costs for waste disposal, companies can save real money. There also have been a number of educational programs on source reduction, e.g., EPA's Waste Wi$e program, sponsored by the public sector in an effort to reduce waste generation.

While source reduction is difficult to measure for the waste stream as a whole, it is possible to measure on a product or site-specific basis. In the most recent EPA characterization update, source reduction is quantified for three example products: refrigerators, plastic grocery sacks, and newspapers (EPA 1997). In each instance, the manufacturers saved money by saving materials, but other benefits also accrue: energy savings, reduced disposal costs, and collection and landfill savings.

While there is not universal agreement on how to define source reduction, diversion, etc., some generally accepted terms are shown in Figure 5-1. Actions such as design changes and materials substitutions, changes in purchasing habits, changes in industrial practices, increased reuse and other changes in use patterns, and backyard composting and grasscycling (leaving grass clippings on the lawn) are all classified as source reduction. These practices occur before MSW is *generated*, as defined for the EPA characterization reports.

Figure 5-1. Illustrations of diversion from landfill



After the MSW is generated, e.g., put at the curb or otherwise taken somewhere for disposal or recycling, waste reduction or diversion measures can be taken. These include recovery for recycling or composting. Combustion can also be defined as diversion if the goal is to divert materials from the landfill. In fact, combustion is a very good diversion technique because the ash remaining after combustion is about 10 percent of the volume of the input MSW, and approximately 25 to 30 percent of the input weight. EPA characterizes both landfill and combustion as disposal, so combustion therefore would not be diversion under their definition.

It appears that economic pressures brought about by a very competitive worldwide economy are leading companies and communities to take a serious look at both source reduction and waste diversion. While these activities have not reversed the growth in generation of municipal solid waste, they apparently are having an effect on the *rate of growth.* While landfills will still be needed in 2010 and beyond, it appears that they will play a reduced role in MSW management, at least in percentage of MSW managed. In fact, the tonnage and percentage of MSW going to landfills peaked in the mid-1980s, and the percentage dropped below 60 percent for the first time in 1995.

Municipal Solid Waste Generation

To provide a baseline projection of what might happen to municipal solid waste management between now and the year 2010, it is first necessary to project MSW generation (Table 5-1). Generation is taken from the recent EPA report, ***Characterization of Municipal Solid Waste in the United States: 1996 Update.*** Projections of municipal solid waste generation prepared for EPA are based on the assumption that generation will continue to grow at a rate higher than population growth, but lower than growth of Gross Domestic Product (GDP). This is consistent with past experience.

Generation is thus projected to grow at a rate of 1.3 percent annually compared to Bureau of the Census projections of population growth at 0.8 percent annually and estimated GDP growth of 2.2 percent annually. In 2000, generation is projected to be 221.7 million tons, up from 208.1 million tons in 1995; generation in 2010 is projected to be 253 million tons.

Although per capita growth of yard trimmings is projected to decline due to source reduction measures, overall per capita generation of MSW is projected to increase from 4.3 pounds per person per day in 1995 to 4.4 pounds per person per day in 2000 and 4.7 pounds per person per day in 2010. (Note that these projections do not assume any marked increases in source reduction other than for yard trimmings.)

Table 5-1

GENERATION AND RECOVERY HISTORY AND PROJECTIONS: POSTCONSUMER MSW
30% RECOVERY IN 2000; 35% IN 2010
(In thousands of tons and percent)

	Total							
	Generation			Recovery				
	000 tons	Annual tons Increase	Annual % Increase*	000 tons	% of Generation	Annual Increment	Annual tons Increase	Annual % Increase*
1989	192,250			31,600	16%			
1990	197,300	5,050	2.6%	33,850	17%	0.7%	2,250	7.1%
1991	196,880	-420	-0.2%	37,690	19%	2.0%	3,840	11.3%
1992	202,210	5,330	2.7%	41,420	20%	1.3%	3,730	9.9%
1993	205,400	3,190	1.6%	44,840	22%	1.3%	3,420	8.3%
1994	209,630	4,230	2.1%	51,970	25%	3.0%	7,130 **	15.9%
1995	208,050	-1,580	-0.8%	56,190	27%	2.2%	4,220	8.1%
2000	221,700	2,730	1.3%	66,700	30%	0.6%	2,100	3.5%
2010	253,000	3,130	1.3%	88,000	35%	0.5%	2,130	2.8%

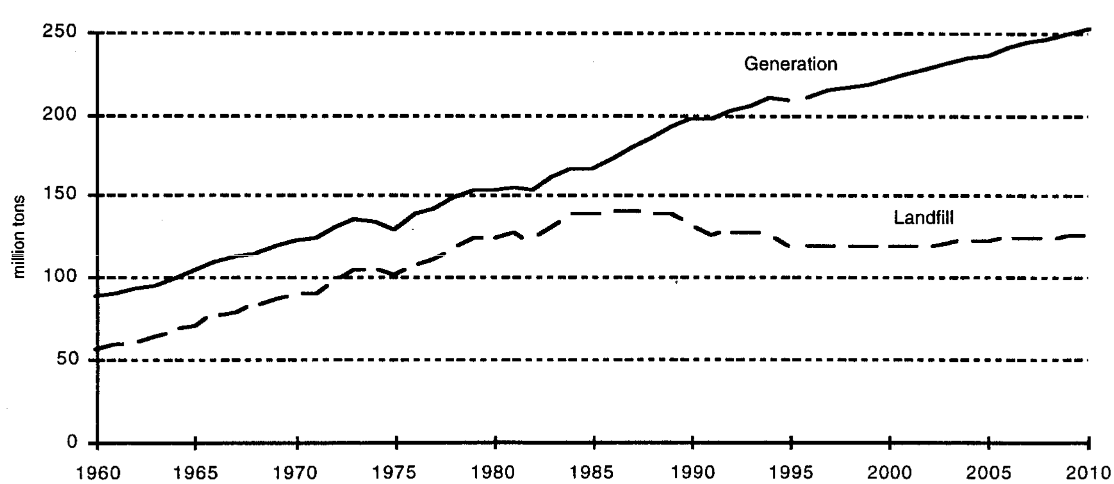
* Tonnage increase divided by previous year generation or recovery.
** There was a large increase in recovery of paper and paperboard 1993–1994.

Source: Franklin Associates, Ltd.

As Figure 5-2 illustrates, discards of MSW to landfill increase very slowly under the recovery scenarios shown in Table 5-1 and discussed in more detail later in this chapter.

Continuing past trends, paper and paperboard, plastics, and wood are projected to be the fastest growing materials in MSW. However, projections of

Figure 5-2. Historical and projected MSW generation and landfill (30% recovery in 2000 and 35% recovery in 2010)



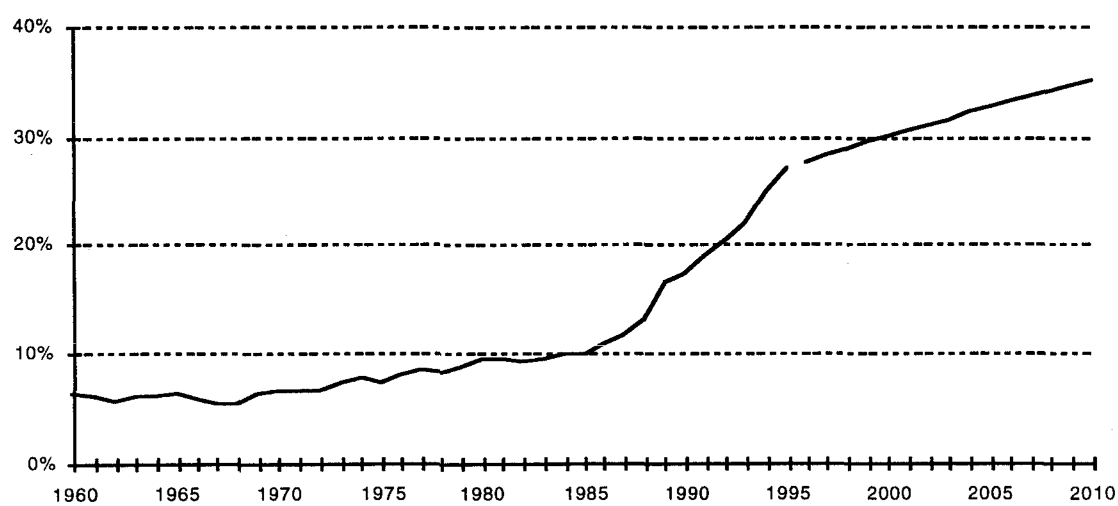
paper and paperboard have been lowered somewhat from those made in the past. Growth of newsprint has slowed due to decreased newspaper readership and source reduction measures by newspaper publishers. Paper packaging has also experienced some losses to other materials, especially plastics. Generation of other materials, while continuing to grow, has shown slower rates of growth than in previous years. Available information on food wastes has been very sketchy. It is possible that the estimates in the 1997 EPA report are too low, but no revisions were made for this report.

Recycling and Composting

Projections. We prepared projections of recovery for recycling and composting using a scenario of 30 percent recovery in 2000 and 35 percent in 2010. These scenarios, which are consistent with the most recent EPA characterization report, project continued growth in recovery rates for recycling and composting, although the growth is expected to be slower than rates experienced in the earlier years of the 1990s (Table 5-1 and Figure 5-3).

While the *tonnage* increase in recovery has generally ranged from 3 million tons to 4 million tons or more annually since 1989, we are projecting about 2 million tons annually from 1995 to 2010. The recovery rate would increase less than one percent each year from 1995 to 2000. Stated another way, the annual percentage increase in recovery (increase in tonnage recovered divided by the previous year's recovery) would decline from 8 percent in 1995 to about 3.5 percent between 1995 and 2000 and less than 3 percent between 2000 and 2010, indicating that a level of maturity will have been reached for materials recycling and yard trimmings composting.

Figure 5-3. Historical and projected MSW recovery rates



Our scenarios to reach 30 percent recovery in 2000 and 35 percent recovery in 2010 are summarized in Table 5-2. To reach the overall 30 percent recovery rate in 2000, recovery rates for most products are only modestly higher than rates

Table 5-2

A SCENARIO TO REACH 30 PERCENT RECOVERY IN 2000 AND 35 PERCENT RECOVERY IN 2010

RECOVERY RATES FOR SELECTED PRODUCTS

	1995	2000	2010
Durable Goods			
Steel and iron in major appliances	80%	83%	85%
Rubber tires	18%	20%	25%
Automotive batteries	96%	97%	98%
Steel and iron in other durables	16%	22%	33%
Other products	4%	5%	6%
Durable Goods Subtotal	17%	18%	20%
Nondurable Goods			
Newspapers	53%	54%	65%
High grade office papers	44%	44%	51%
Magazines and catalogs	25%	25%	30%
Other printing-writing papers	15%	15%	18%
Textiles	16%	21%	24%
Other products	0%	2%	2%
Nondurable Goods Subtotal	24%	24%	28%
Containers and Packaging			
Glass bottles and jars	27%	29%	40%
Steel cans	57%	65%	75%
Aluminum cans	63%	70%	75%
PET soft drink bottles	46%	54%	60%
HDPE natural bottles	30%	35%	46%
Other plastic containers	13%	15%	22%
Corrugated boxes	64%	71%	73%
Folding cartons	20%	20%	22%
Wood pallets and boxes	14%	16%	21%
Other packaging	6%	8%	15%
Containers and Packaging Subtotal	38%	42%	48%
Yard trimmings	30%	40%	50%
Food wastes	4%	6%	9%
Other	0%	0%	0%
Total Municipal Solid Waste	27%	30%	35%

These percentages represent possible scenarios to reach a goal. Many other combinations are possible.

Source: Franklin Associates, Ltd.

achieved in 1995. To achieve an overall 35 percent recovery rate in 2010, recovery of most products will need to be increased substantially.

Projected Recovery by Product. For the year 2010, we projected high rates of recovery for many products: 85 percent for steel and iron in appliances, 65 percent for newspapers, 51 percent for high grade office papers, 75 percent for steel cans, 75 percent for aluminum cans, 60 percent for PET soft drink bottles, 73 percent for corrugated boxes, and 50 percent for yard trimmings. We believe that these recovery rates are achievable, although not without effort.

Projected Recovery by Material. A summary of these scenarios by material category is shown in Table 5-3. To reach 35 percent recovery in 2010, we assumed 47 percent recovery of paper and paperboard, 46 percent for steel and iron, 36 percent for glass, and 50 percent for yard trimmings. These four materials represent 64 percent of the projected generation of MSW in 2010, so high rates of recovery for them is necessary if the overall recovery rate is going to continue to increase. Also, the infrastructure for collecting and processing these materials is already well developed.

Projected Recovery by Source. In any consideration of the future of recovery for recycling and composting, it is essential to consider the residential and commercial MSW streams separately. These two waste streams are quite different in nature, and the infrastructures used for collection are also very

Table 5-3

A SCENARIO TO REACH 30 PERCENT RECOVERY IN 2000 AND 35 PERCENT RECOVERY IN 2010

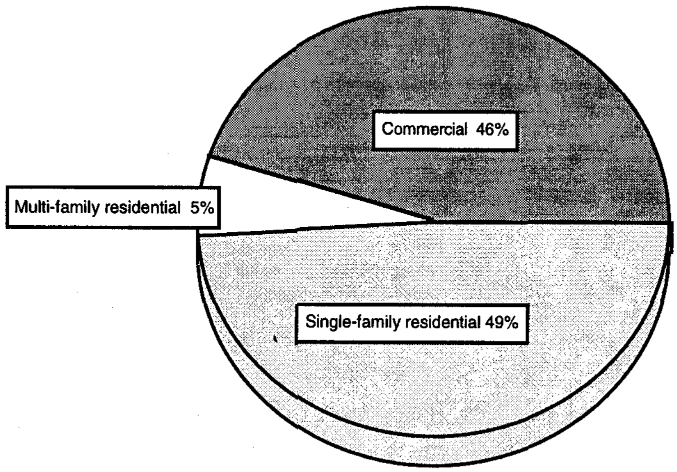
RECOVERY RATES BY MATERIAL

	1995	2000	2010
Paper and paperboard	40%	42%	47%
Glass	25%	26%	36%
Steel and iron	37%	40%	46%
Aluminum	35%	41%	43%
Plastics	5%	7%	10%
Wood	10%	11%	15%
Yard trimmings	30%	40%	50%
Food wastes	4%	6%	9%
Other materials*	15%	17%	19%
Total Municipal Solid Waste	27%	30%	35%

* Rubber and leather, textiles, miscellaneous.
These percentages represent possible scenarios to reach a goal.
Many other combinations are possible.

Source: Franklin Associates, Ltd.

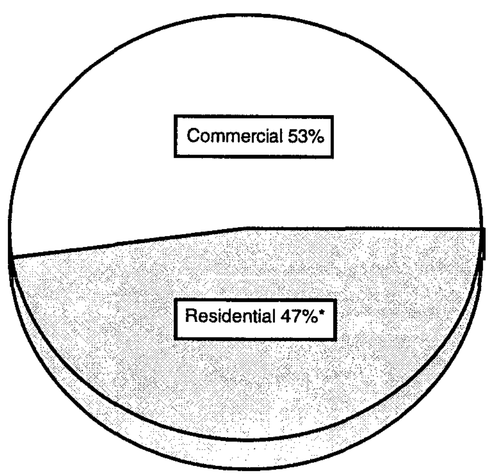
Figure 5-4. Projected sources of MSW generation, 2010



different. By the year 2010, we project that MSW sources by generation will be 49 percent single-family residences, 5 percent multi-family residences, and 46 percent commercial (Figure 5-4 above). (Note that waste management companies would generally classify the multi-family wastes as commercial.)

A detailed analysis of the 35 percent recovery scenario presented in Table 5-2 is shown in Table 5-4. While 54 percent of MSW generated in this scenario is residential, less than 50 percent of recovery is projected to come from residential sources (Figure 5-5). Most of the projected residential recovery (88 percent) would

Figure 5-5. Projected sources of MSW recovery, 2010



* Includes multi-family housing

Table 5-4

PROJECTION OF MSW GENERATION AND RECOVERY BY SOURCE, 2010
35 PERCENT RECOVERY SCENARIO
(in thousands of tons)

	Total	Residential Sources*			Commercial Sources			Total Recovery	
	Generation	Generation	Recovery	Percent Recovery	Generation	Recovery	Percent Recovery	000 tons	Percent
DURABLE GOODS									
Major appliances (steel & iron only)	2,740	270	0	0%	2,470	2,320	94%	2,320	85%
Rubber tires	4,500	230	10	4%	4,270	1,110	26%	1,120	25%
Auto batteries (lead, plastics)	1,270	60	50	83%	1,210	1,190	98%	1,240	98%
Miscellaneous durables (steel & iron)	4,510	1,340	250	19%	3,170	1,250	39%	1,500	33%
All other durables	25,270	18,070	700	4%	7,200	700	10%	1,400	6%
Total Durables	38,290	19,970	1,010	5%	18,320	6,570	36%	7,580	20%
NONDURABLE GOODS									
Newspapers (ONP)	13,860	11,780	8,500	72%	2,080	500	24%	9,000	65%
High grade office papers	8,900	900	220	24%	8,000	4,280	54%	4,500	51%
Magazines and catalogs (OMG)	5,880	3,920	1,200	31%	1,960	300	15%	1,500	26%
Other printing-writing papers	15,330	9,960	2,400	24%	5,370	600	11%	3,000	20%
Other papers	10,680	5,440	250	5%	5,240	20	0%	270	3%
Subtotal papers	54,650	32,000	12,570	39%	22,650	5,700	25%	18,270	33%
Textiles (clothes & linens)	7,130	4,630	1,450	31%	2,500	250	10%	1,700	24%
Other nondurables	10,940	8,870	150	2%	2,070	50	2%	200	2%
Total Nondurables	72,720	45,500	14,170	31%	27,220	6,000	22%	20,170	28%
CONTAINERS AND PACKAGING									
Cans, bottles, and jars									
Glass bottles and jars	13,000	10,660	4,800	45%	2,340	400	17%	5,200	40%
Steel cans	3,060	2,600	2,100	81%	460	200	43%	2,300	75%
Aluminum beverage cans	1,930	1,500	1,250	83%	430	200	47%	1,450	75%
Plastics									
PET soft drink bottles	900	720	480	67%	180	60	33%	540	60%
HDPE natural bottles	860	770	380	49%	90	20	22%	400	47%
Other containers	1,700	1,360	360	26%	340	20	6%	380	22%
Subtotal plastics	3,460	2,850	1,220	43%	610	100	16%	1,320	38%
Subtotal cans, bottles, jars	21,450	17,610	9,370	53%	3,840	900	23%	10,270	48%
Corrugated boxes	39,280	3,960	800	20%	35,320	28,000	79%	28,800	73%
Folding cartons	7,900	4,740	1,400	30%	3,160	300	9%	1,700	22%
Wood pallets and boxes	14,600	0	0	0%	14,600	3,000	21%	3,000	21%
Other packaging	11,660	9,110	1,200	13%	2,600	180	7%	1,380	12%
Total containers and packaging	94,890	35,420	12,770	36%	59,470	32,380	54%	45,150	48%
Total products and packaging	205,900	100,890	27,950	28%	105,010	44,950	43%	72,900	35%
Percent of total recovery			38%			62%			
Yard trimmings	27,400	24,660	13,500	55%	2,740	200	7%	13,700	50%
Food wastes	16,100	8,050	80	1%	8,050	1,320	16%	1,400	9%
Miscellaneous inorganic wastes	3,600	1,800	0	0%	1,800	0	0%	0	0%
TOTAL MSW	253,000	135,400	41,530	31%	117,600	46,470	40%	88,000	35%
Percent of total generation		54%			46%				
Percent of total recovery			47%			53%			

* Includes both single-family and multi-family residences.
This scenario represents one way to achieve 35 percent recovery. Many other combinations are possible.

Source: Franklin Associates, Ltd.

come from old newspapers; old magazines; other printing-writing papers (e.g., mail); cans, bottles, and jars; folding cartons; and yard trimmings. By contrast, in this scenario most of the recovery from commercial sources (88 percent) would come from steel and iron in durable goods; tires; automotive batteries*; office papers; corrugated boxes; wood pallets; and food wastes.

Recycling and Composting Outlook. As described earlier in this chapter, the 35 percent recovery projection for 2010, while based on a slowing in rate of increase of recovery, still represents a substantial increase in tonnage collected. We therefore developed some collection scenarios to test whether this level of recovery is feasible.

Curbside Collection. To project curbside recovery of recyclable materials in 2010, we used a scenario similar to the expanded case curbside collection with yard trimmings composting developed in Chapter 3. We used projections of residential MSW generation from Table 5-4 and Census Bureau projections of the number of residences in 2010. We assumed that the percentage of single-family residences (78 percent of total residences) would be the same as in 1994.

We further assumed that 60 percent of single-family households would have curbside collection of recyclable materials available to them, that 65 percent of those households would participate, and that recovered materials would be captured at rates ranging from 40 to 90 percent. Using these assumptions, we estimated that 23.4 million tons of materials would be collected curbside, which would amount to about 9 percent of total MSW generation and about 27 percent of total recovery (Table 5-5).

Drop-off/Buy-back Collection. Projections of collection through drop-off and buy-back programs are difficult because not much data is available to provide a basis. Our scenario assumes that 13.1 million tons of materials could be collected in 2010 through drop-off, buy-back, and deposit programs. (We assumed that existing beverage container deposit laws would still be in effect.) A substantial portion of the assumed recovery would come from collection of old newspapers.

Drop-off/buy-back/deposit programs would collect about 5 percent of total MSW generated under this scenario, and about 15 percent of total recovery (Table 5-5).

Commercial Collection. Collection from commercial establishments and multi-family residences was combined in this scenario, since the infrastructure is similar (Table 5-5). We estimated that 51.5 million tons of recovered materials

* While some durable goods, i.e., tires and automotive batteries, may be recovered directly from residential sources, the usual infrastructure for collecting these products is through commercial dealers and salvage operations.

Table 5-5

A COLLECTION SCENARIO TO ACHIEVE 35 PERCENT RECOVERY IN 2010
(In millions of tons and percent)

Collection Source	MSW Recovery	% of Total MSW Generation	% of Total MSW Recovery
Single-family curbside	23.4	9%	27%
Drop-off/buy-back/deposits	13.1	5%	15%
Commercial/multi-family			
Steel and iron in durables	3.6	1%	4%
Tires, batteries	2.3	1%	3%
High-grade office papers	4.3	2%	5%
Corrugated boxes	28.0	11%	32%
Wood pallets	3.0	1%	3%
All other	10.3	4%	12%
Total commercial	51.5	20%	59%
Total collection	88.0	35%	100%

This scenario represents one way to achieve 35 percent recovery. Many other combinations are possible. Details do not add to totals due to rounding.

Source: Franklin Associates, Ltd.

would come from commercial/multi-family sources in 2010. This amounts to about 20 percent of total MSW generation, and about 59 percent of total recovery.

Corrugated boxes would make up over half of commercial collection, with office papers, wood pallets, and steel and iron (from appliances) also very large contributors to total commercial collection.

Factors Affecting Future Recovery. A number of factors affect present and future recovery rates, and achieving the higher rates projected depends upon resolution of a number of issues. These factors and issues include:

- **Export Demand.** Exports of recovered materials can have a major effect on market demand in the U.S. This is particularly true for recovered paper products, but markets for plastic resins and metals are also affected by export markets (see Chapter 4). For example, exports of recovered paper increased 35 percent between 1994 and 1995, then dropped by 31 percent from 1995 to 1996 (AF&PA 1997). Fluctuations like these cause major changes in demand and prices for recovered materials.

- **Unanticipated Regulations.** Regulations enacted by states, or more likely, local governments can have a dampening effect on materials recovery efforts in the private sector. An example would be imposing requirements on collectors that cannot be met reasonably or economically. Any regulation that makes collection more expensive works against increasing recovery.

- **Consumer Preference.** To create a market for recovered materials, someone must be willing to purchase products that utilize the materials. While there are numerous programs aimed at increasing demand for recovered products, there is concern as to whether consumers are really interested. There's some evidence that the answer is yes, but the interest may be "background" rather than intense. A Roper Starch survey in 1996 indicated that 48 percent of Americans claim they are willing to pay a premium for "environmentally friendly" products, but most of these say they will pay only a small premium—an average of 4.5 percent (Speer 1997).

- **Level of Government Funding.** Many states have provided funding to local recycling or composting programs. These grants have funded such diverse activities as purchasing equipment or hiring recycling coordinators. In a 1997 annual survey, ***BioCycle*** identified 37 states funding grant programs in their most recent fiscal year (BioCycle May 1997). However, some states have ceased or reduced the level of funding (notably Michigan and Florida). This has the potential to affect the level of recycling in those states.

  Local governments often have tight budgets and may not want to subsidize recycling/composting activities in periods of low income for recovered materials. This is especially true where local commitment to recycling is low. On the other hand, local governments often have good reasons for recycling, e.g., to avoid landfill costs and postpone siting a new landfill. Also, when citizens have grown accustomed to recycling, it is difficult for local governments to take away the service. For example, Miami, Florida considered canceling or cutting back curbside collection of recyclables to save money, but there were so many citizen protests that the city commission voted unanimously not to take away this service (Recycling Times May 26 and July 21, 1997).

- **Contamination Issues.** Markets for recovered materials (e.g., paper mills and glass plants) need clean, uncontaminated materials. Examples of contamination include colored glass mixed in with clear (flint) glass, a plastic bottle made of a different resin than that specified, newspaper in a bale specified to be white ledger (office papers), and glass, plastic, or food in a bale of recovered paper. This contamination may make recovered materials unusable, and, at a minimum, will reduce the value of the materials.

  As communities' efforts shift to lower-cost, single-stream curbside recyclable materials collection programs in an effort to increase collection and lower costs, there is a collision with end users' demand for increasingly higher quality levels, particularly for paper and paperboard. This can be a serious impediment to achieving projected recovery rates in the 21st century.

- **Product Performance at Higher Rates of Recycling.** This concern primarily applies to paper recycling. When paper is recycled, there is some loss of short fibers in the process. After repeated recycling, the fibers may become so short that strength is lost, which must be made up by making the weight of the product heavier or by introducing virgin fibers into the pulp. As certain paper products (newspapers, corrugated boxes) reach higher and higher levels of recovery, product performance could become a limiting factor.

Does Recycling Have a Future? The recycling component of MSW management has experienced some hard times recently due to temporary lower demand than was experienced in 1994–1995 and poor market prices for many recovered materials (as discussed in Chapter 4). In addition to some retrenchment by the large waste management firms, other collectors and processors of recovered materials have also closed facilities. In a period of general austerity in the public sector, some states have been cutting back on recycling grants, and a few local governments have reduced their recycling programs. Other limiting factors were discussed in the paragraphs above.

In the midst of these negative or at least confusing events, some critics have been predicting that recycling and composting will stagnate or perhaps increase very slowly. They foresee that local governments will abandon curbside collection programs as they discover that these programs almost always carry additional costs. Are these negative predictions correct?

We would argue that, while there will be some instances where local governments curtail recycling activity, overall recycling and composting will continue to increase. A recent survey of 1000 adults sponsored by COPE (the seventh in a series of surveys) shows that a majority (57 percent) say believe that the environment is a "very serious" or "extremely serious" issue. COPE found that reported concern for the environment has remained relatively constant over time. Thus, the environment may have become a "background" issue that persists, even though other issues (e.g., crime, the economy) may be receiving more attention at any given time. A vast majority (79 percent) of those surveyed reported taking some action to help the environment in the past three months, most commonly by recycling (COPE 1996).

Also, in communities that have curbside collection, many people have formed the habit of recycling and like the convenience. What's more, they will complain to their elected officials if a convenience they perceive as a government service is taken away. Under these circumstances, elected officials must balance the desire to keep taxes or service fees low with the desire to keep serving the public. We believe that most elected officials will try to keep the service, although operational economies may (and should) be instituted. (See Chapter 2.)

Undoubtedly, there will be some communities where the cost of expanded collection for recycling and composting will seem too great, and recovery will "stall" at rates lower than those projected. In other communities, however, we believe that the desire or need for greater diversion of wastes from disposal (e.g., landfill) will stimulate the additional effort required to reach rates even higher than the 35 percent projected for 2010. Indeed, some communities already are claiming recovery rates above 35 percent.

MSW Combustion

Projections. The projections of municipal solid waste combustion are taken from the 1996 EPA characterization update (Table 5-6 and Figure 5-6). This is a low growth scenario—less than one percent increase in throughput of MSW combusted per year. Combustion of MSW as a percentage of generation is thus projected to be about the same in 2010 as in 1995. If projected combustion is, however, calculated as a percentage of MSW remaining after recovery for recycling and composting, then combustion in 2010 would be 24 percent of the remainder.

Table 5-6

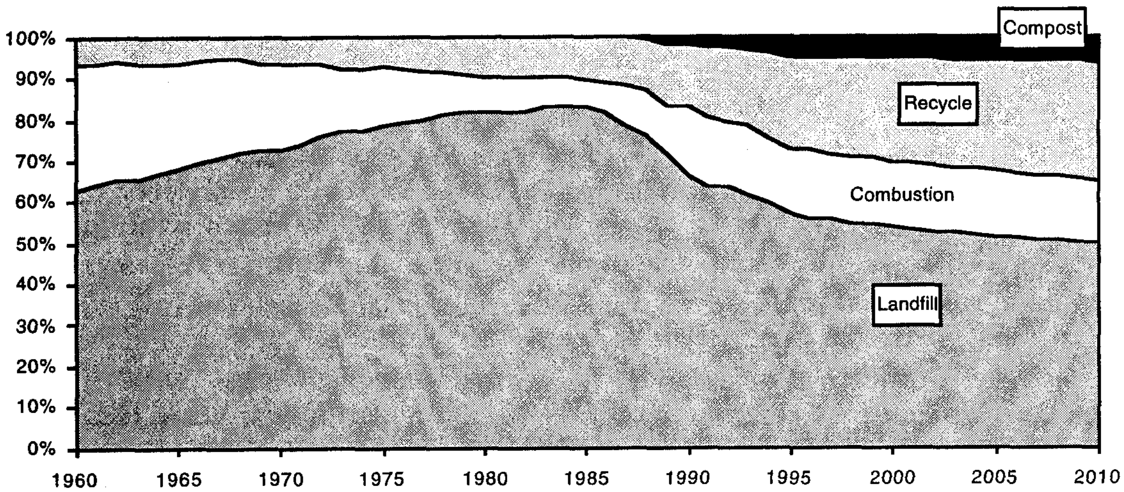
PROJECTIONS OF MUNICIPAL SOLID WASTE MANAGEMENT, 2000 AND 2010
(30 PERCENT RECOVERY IN 2000; 35 PERCENT IN 2010)
(In thousands of tons and percent)

	1995	2000	2010
Generation	208,050	221,700	253,000
Recovery			
For recycling	46,620	55,000	72,900
For composting	9,570	11,700	15,100
Total recovery	56,190	66,700	88,000
% of generation	27%	30%	35%
Discards after recovery	151,860	155,000	165,000
Combustion	33,470	36,000	39,000
% of generation	16%	16%	15%
% of discards after recovery	22%	23%	24%
Landfill*	118,390	119,000	126,000
% of generation	57%	54%	50%

* A relatively small portion of the tonnage shown as landfilled is actually littered or self-disposed on-site.

Source: Franklin Associates, Ltd.

Figure 5-6. Management of municipal solid waste, 1960 to 2010 (in % of total generation)



Outlook. Combustion of MSW, which is now almost all done in waste-to-energy (WTE) facilities, has some positive aspects, but also has negative factors that must be overcome if combustion is to grow faster than our projections. Both sides of the outlook for increased combustion of MSW are discussed below.

Image. WTE has a negative image with many environmental groups, which frequently has been transmitted to the general public. Two main themes of these groups are that WTE displaces recycling activities and that WTE has a negative environmental impact. We see little truth in either of these arguments.

The WTE industry association, Integrated Waste Services Association (IWSA), claims that communities with WTE facilities achieved a 26 percent recycling rate in 1995 (IWSA 1996), which is comparable to the national average. If a WTE facility is properly sized to allow for materials recovery for recycling (this has not always been true in the past), there should be no problem. Recovery of inorganic materials (glass, metals) has a beneficial effect on combustion. Also, removal of yard trimmings, which have a high moisture content, for composting is beneficial to a WTE facility (Clark 1996). In addition, more than 700,000 tons of steel and iron were recovered from WTE facilities in 1995 (IWSA 1996), usually by magnetic separation from the ash residues.

The negative environmental image seems to go back to the days when waste was often incinerated with no pollution controls and no energy recovery. The fact is that incineration is almost gone (an estimated 2 percent of total combustion design capacity in 1996, based on IWSA figures). Emissions from WTE facilities are now more closely regulated than those from landfills or fossil fuel power plants (Licata 1996), and disposal of ash residues is also regulated. Thus, it would seem that WTE facilities are held to a higher standard than other waste management alternatives, or other sources of energy.

Economics. A WTE facility generally has two sources of income: tipping fees paid by those bringing in wastes, and revenues received from sales of recovered energy and materials. Because the pollution controls required of WTE facilities are so expensive, these facilities often have difficulty being competitive with landfill tipping fees (except in a few parts of the country, where landfilling is also expensive). WTE tipping fees in Alabama, Florida, Hawaii, Michigan, Minnesota, New Jersey, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, and Washington are all considerably higher than landfill fees (Magnuson 1997). However, the comparison is more favorable to WTE in Massachusetts, where landfill is also expensive. In other states (California, Indiana, New Hampshire, New York), WTE and landfilling tipping fees are approximately equal. In a number of other states, there are no WTE facilities.

In the late 1970s and early 1980s, when many WTE facilities were being built, the U.S. had experienced an energy crisis that made the economics of alternative fuel sources such as WTE look very favorable. Now, however, when selling an energy product (steam or electricity), a WTE facility must compete with current comparatively lower prices for fossil fuels.

Efficiency. Another significant problem that is both economic and environmental in nature is that MSW waste-to-energy plants are less efficient at converting the heat content of MSW to energy, e.g., power, than utilities designed for specific fuels, e.g., coal. There are a number of valid reasons for this lower efficiency, but most can be attributed to the heterogeneous composition of MSW, the lower heat content, and the technical limits on temperature and pressure of the boilers. Thus, investments in power generating equipment and pollution control equipment do not result in a favorable return to reach a high output (and thus revenue).

A simple calculation will illustrate the dilemma. If a MSW-to-electricity facility operates at 19 percent efficiency and a coal-fired power plant operates at 32 percent efficiency, then it takes 68 percent more Btu from MSW to deliver the same quantity of electricity as a coal-fired plant. With concerns about global climate change coming to the fore, the additional carbon dioxide produced by WTE compared to coal may become another barrier to overcome in the future. If, however, combustion is to take place under any circumstances, it would seem preferable to produce usable energy rather than release the carbon dioxide with no benefit realized.

Flow Control. Many WTE facilities have contracts with units of government (e.g., a city or county) to deliver wastes at a stated tipping fee. Local governments have used a mechanism called flow control to direct that all wastes collected in their jurisdictions be delivered to the facility, even though tipping fees might be lower elsewhere. Thus the facilities could operate with long-term guaranteed waste supplies and tipping fee income.

In 1994, however, the U.S. Supreme Court overturned a New York flow control ordinance, holding that it interfered with interstate commerce (Frischkorn 1997). Since then, state and federal courts and arbitrators in a number of jurisdictions (e.g., New Jersey, Pennsylvania, Washington, and Wisconsin) have also ruled that some flow control measures discriminate against interstate commerce (Waste News October 14, November 18, 1996; January 27, February 3, February 24, April 28, 1997). Congress so far has not passed any legislation clarifying the issue. The resulting uncertainty about flow control of waste to a facility makes implementation more difficult because of financing issues.

Utility Deregulation. In 1992 Congress passed the Energy Policy Act requiring all electric utilities to share their transmission lines, and in June 1996, the Federal Energy Regulatory Commission (FERC) approved an "open access" rule that lifts restrictions on where utilities can sell their commodity (Arnold 1996). The impact of these rules changes on the WTE industry is unclear, but they should make it possible for facilities to sell electricity in regions where a higher price could be obtained.

Like flow control, utility deregulation introduces some uncertainty into facility planning and implementation. This could delay some project financings until the impact of the rules is clarified.

Summary. Since the planning and implementation period for a large WTE facility can be as long as 10 years, and there are some negative factors in the current situation, we are not projecting any substantial growth in WTE capacity before 2010. For WTE to grow substantially, one or more of the following factors need to be in place:

- Tipping fees for WTE need to compare favorably with fees for landfilling. This can happen in areas of the country with high landfill costs.

- Revenues received for energy products need to increase by improving the efficiency of the waste-to-energy process.

- The local governmental units responsible for issuing permits must be convinced that WTE is a positive factor for the community. Both economic and environmental factors are important to communities.

- Legislative uncertainties need to be resolved.

MSW Landfilling

The remainder of MSW left after recovery for recycling, composting, and combustion is assumed to be landfilled (Table 5-6 and Figure 5-6). (Everyone knows that some MSW is littered and self-disposed on site, but we believe that this is a small amount in terms of percentage.) The *percentage* of MSW landfilled has declined from about 83 percent in 1985 to 57 percent in 1995, with a projection of 50 percent in 2010. Estimates of *tonnage* landfilled have declined from 133.5 million tons in 1985 to 118 million tons in 1995, with a projection of 126 million tons in 2010.

Sensitivity of Results to Variations

Since it is difficult to project either MSW generation or recovery with certainty, it is important to note that variations in either recovery (the numerator of the equation) or generation (the denominator) will cause recovery rates to vary. To illustrate, Table 5-7 is included. Our projections for the year 2000 are used for this example.

Table 5-7

ILLUSTRATION OF SENSITIVITY OF RECOVERY RATES TO VARIATIONS IN GENERATION OR RECOVERY
(Using projections for 2000 as an example)

First assume that recovery stays constant and generation varies:

	Generation	Recovery	% Recovery
Projected generation	221,700	66,700	30%
5% higher	232,790	66,700	29%
5% lower	210,620	66,700	32%

Next assume that generation stays constant and recovery varies:

	Recovery	Generation	% Recovery
Projected recovery	66,700	221,700	30%
5% higher	70,040	221,700	32%
5% lower	63,370	221,700	29%

Source: Franklin Associates, Ltd.

If projected recovery stays constant and generation is varied 5 percent higher or 5 percent lower than the projection, then the projected recovery rate (32 percent) could be as low as 31 percent or as high as 34 percent. If generation is held constant and recovery is varied 5 percent higher and lower than the projected tonnage, the variation would be the same—between 31 percent and 34 percent rather than the projected 32 percent. Thus, the boundary for the most likely case is reasonable given the uncertainty.

IS A FUNDAMENTAL CHANGE IN THE MAKING?

The Nature of the MSW Stream and its Management

Solid waste management is in a difficult transition period, although most long-term trends described here appear to be intact. The most intriguing recent development, however, occurred in 1995, and a very preliminary 1996 analysis appears to confirm that 1995 was not an anomaly.

The 1995 MSW total generation data reveal a decline compared to 1994, even though Gross Domestic Product (GDP) growth was relatively strong. Part of the decrease in generation was attributed to diversion of yard trimmings. However, products declined also, with most of the decrease being in paper products. With higher recovery (the numerator) and lower generation (the denominator), the recovery rate increased significantly—from 25 percent to 27 percent—in 1995 compared to 1994.

We developed some preliminary estimates for 1996, and it appears likely that generation again decreased, with paper products and yard trimmings as the major sources of the decline. Paper *recovery* tonnage was also down in 1996, largely due to a 31 percent decline in recovered paper exports in 1996 as compared to 1995. Thus, we believe that MSW generation will be down somewhat, and that the recovery rate will be between 27 and 28 percent, or essentially flat.

If our preliminary estimates for 1996 are on target, then generation of products and packaging *and* total MSW have declined for two years in a row (1995 and 1996). The only other period we can identify where MSW generation declined two years in a row was the major recession years 1974–1975. At the same time, recovery increased every year since 1990, including 1996 (if our preliminary estimate is correct).

Two years do not make a trend, but it does appear that growth of MSW generation is slowing. Much of this is due to the decline in yard trimmings placed at the curb for collection, but other products, especially paper, appear not to be growing as fast as the economy. The possible effects of these changes, if real, are intriguing to contemplate. If the growth rate for generation of MSW slows while recovery continues to increase, there obviously will continue to be less MSW tonnage available for combustion or landfill. This virtually assures that there will continue to be consolidation of the "traditional" waste management companies, i.e., those that collect and landfill MSW.

As the quantity of MSW available for landfill or combustion decreases, costs per ton tend to increase. In addition, with fewer tons available, total revenue will decline, and this may make some facilities become marginally economical (Wall Street Journal May 12, 1997).

The projected increase in recovery for recycling and composting will favor collectors and processors that can be efficient and economical in their operations. Whether public or private, this part of the industry will continue to evolve toward more efficient operations.

Will We Change Our Definition and Perception of "Waste"?

There is now a movement to get away from the terminology "waste" in recognition of the potential for beneficial use of materials at the end of their original purpose. While these changes in terminology come slowly, the discussion illustrates some changes in the way interested parties are thinking.

No matter how we define the "stuff" that people no longer want or need, our collective thinking on how to manage it has gone through more than one evolution. From the frugality of the 1930s ("Use it up, wear it out, make it do, or do without"), to the sacrifices of the World War II years, to the years of prosperity when many people felt they could throw away unwanted items, to the revival of interest in resource conservation (both energy and materials) in the 1970s, to the fear that we were running out of landfill space in the 1980s, to the present when we see elements of all these perceptions plus an awareness of economic realities, Americans have continually redefined waste management and resource management goals.

The Stakeholders

There are many different groups within and outside the U.S. (stakeholders, to use a currently popular term) that have different perspectives on waste management/resource management goals. These include:

- *Citizens*—the taxpayers and consumers who ultimately pay the price of all goods and services, including waste/resource management.

- ***Local elected and appointed government officials***, who usually have direct responsibility for residential waste management services, although the services may be contracted to private firms. These officials are directly responsible to the local citizens; they also are subject to state and federal regulations.

- ***State elected officials and government agencies***, which have considerable responsibility for the health and safety of citizens and for regulating waste management, including approval of facility siting. Many states carry these responsibilities further by encouraging waste management practices deemed to be advantageous, such as recycling.

- ***Federal elected officials and agencies,*** which can greatly influence waste management practices through regulatory powers and education.

- ***Manufacturers of goods,*** who may favor one or more waste management practices depending upon their particular operation. For example, manufacturers of products made from recycled materials need a reliable, reasonably priced materials supply. Also, all manufacturers need waste management services for their facilities.

- ***Service providers***—this group includes waste haulers, landfill owners, combustion facility owner/operators, and processors/handlers of materials recovered for recycling/composting. Consultants in the field also fall into this category.

- ***Commercial organizations,*** which include large and small businesses, e.g., retailers, institutions such as hospitals, transportation providers, and many others. These organizations also require, and must pay for, waste management services.

- ***Environmental groups,*** which tend to see waste management in the context of broader environmental issues: air and water emissions, land use, resource and energy conservation, global climate change, etc.

- ***Interest groups***—the U.S. has a very large number of organizations representing the interests of all the groups already mentioned. These include industry associations, associations of elected and appointed public officials, and environmental and public interest groups.

- ***The worldwide economy*** is also important. Emerging countries in the Pacific Rim provide markets for many of our recovered materials, and when their demand is down (as is the case for the past year or so), our materials markets and demand for recovered materials suffer. To cite another example, regulations and policies of the European Union (EU) affect U.S. companies who market their products in Europe. Also, EU actions tend to influence policies in the U.S.

The Future of MSW Management in the United States

The genius of the American system of government includes the rights of all these disparate and overlapping groups to make their voices heard. Somehow consensus decisions are made, although one group or another may have the "upper hand" at any given time. We believe that we are in one of those periods of rapid evolution in solid waste management. The private sector is being reshaped by the marketplace, and the public sector is also being forced to re-examine its role in MSW management.

We have laid out scenarios projecting how our municipal solid waste could be managed in 2010. Whether these scenarios are accurate or we take another path entirely depends upon the interaction of complicated interests cutting across the entire country. Based on observations of the past three decades, we have arrived at the following conclusions.

Generation of MSW

- While it's too early to be sure, there are some signs that growth in generation of MSW is slowing.

Infrastructure

- Waste management in our large and diverse country will continue to be highly variable from region to region.

Recovery

- Recovery for recycling and composting will continue to increase at a rate faster than many have predicted, but slower than many others would prefer. We believe that 30 percent recovery in 2000 and 35 percent in 2010 is reasonable to expect, though not without effort and cost.

Markets for Recovered Materials

- Markets will continue to be available for recovered materials, but there will always be discontinuities between supply and demand. Some of the available markets will not pay the high prices that collectors and processors would like to have. The worldwide economy will continue to be an extremely important factor for most materials markets.

Economics

- Communities and private waste managers will continue to optimize collection and processing systems, whether the goal is recovery or disposal. These decisions are driven by economics as well as other goals and local circumstances.

Waste-to-Energy

- Waste-to-energy throughput will not increase much unless unforeseen events occur (e.g., greatly increased energy costs).

Landfilling

- Landfilling will continue to be an important part of municipal solid waste management, but percentage of total MSW landfilled will continue to decline.

THE FUTURE FOR MATERIALS RECOVERY

The *national average* recovery scenario for 2010 is developed on the basis of *what it takes* to reach that level of recovery in the 10 years after 2000. Some material recovery rates must reach practical limits to achieve this level of recovery (see Tables 5-2 and 5-4). Whether that will be achieved is dependent upon the priorities that states and local communities place on recovery and/or diversion. In any case, there are major hurdles to be overcome if the trend to increased recovery set in motion in 1990 is to prevail beyond 2000.

The analysis of issues can be segmented into two general MSW sources: (1) commercial, and (2) residential.

Commercial Sources. The commercial sector will respond to economic forces above all else—generally on the basis of cost avoidance vs. conventional solid waste services. Virtually the exclusive domain of private sector activity, the driving forces are strongest for large quantities of material that have active markets. In the commercial sector, these are corrugated boxes, office papers, and steel (from appliances and waste-to-energy facilities). For example, these three categories account for about 95 percent of projected recovery from commercial sources in 2010; corrugated boxes alone account for more than 75 percent of the projected tonnage recovered from commercial sources.

The recovery rates of these key components will be at or near their practical maximum from 2000 on. While recovery of other materials can have a significant effect in a local community from a national viewpoint, not much can be expected to push total recovery of these key components higher.

Residential Sources. Without question, the greatest challenge to continued growth of recovery of materials is from residential sources. In fact, this sector of MSW management has entered a very challenging transition period, and it is difficult at best to say that the future will be as easy as the early to mid-1990s have been. Since our scenario of 35 percent recovery is based on what needs to happen to reach that level, we discuss here the challenges that states and communities must address if their goals are to recover or divert large quantities of materials from residential MSW.

1. Residential curbside collection of recyclable materials will need to expand to cover at least 60 percent of the U.S. population.

2. Cost effectiveness of curbside collection cannot be achieved based on revenue from recovered materials; it is collection costs that drive the economics of curbside collection.

3. Managing curbside collection must be based on the reality that this a service people are willing to pay for, even though the increased cost over conventional collection and disposal is relatively small. There is a benefit in satisfying citizens' desires to participate in an environmentally beneficial activity.

4. To keep participation, set out, and capture rates as high as practical, intense and continuing education will be needed. Also, both increased materials recovery and yard trimmings composting will be needed to reach 35 percent recovery by 2010. To reach 35 percent recovery overall, states with high recovery/diversion achievements will have to offset those states with limited recovery.

5. Private industry will continue to support recovery efforts for materials that can be used. However, they will not likely subsidize collection and processing of materials derived from residential curbside programs.

6. Once in place, the infrastructure to collect, process, and prepare recyclable materials will likely stay, though it may expand and contract as markets fluctuate.

7. The economics of increased recovery of materials is much more burdensome for programs that attempt to push to higher levels of recovery by adding materials or intensifying collection requirements.

8. For those states and communities that wish to increase recovery or diversion beyond 35 percent on average, an added effort and refocus will be required. Specifically, the recovery of mixed paper *where a market exists* will be effective. Beyond that, composting of organic materials such as unrecyclable paper, food wastes, and yard trimmings is the most effective technique leading to recovery above 35 percent on average.

Finally, local communities will be tested with the dual challenges of forcing costs down (e.g., using commingled collection) while responding to the marketplace, which requires high quality recovered materials. Technology has not yet resolved this issue and may not until well into the next investment cycle, about 2005. With recovery for recycling and composting a background issue today, there will continue to be uncertain times in the long transition period.

Chapter 5

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ABBREVIATIONS AND ACRONYMS

AF&PA	American Forest & Paper Association
APC	American Plastics Council
APR	Association of Postconsumer Plastics Recyclers
BLS	Bureau of Labor Statistics
COPE	Council on Packaging in the Environment
EIA	Environmental Industry Associations
EPA	U.S. Environmental Protection Agency
GDP	Gross Domestic Product
HDPE	High density polyethylene
IWSA	Integrated Waste Services Association
MRF	Materials recovery facility
MSW	Municipal solid waste
NAPCOR	National Association for Plastic Container Recovery
OCC	Old corrugated containers
OMG	Old magazines and catalogs
ONP	Old newspapers
PET	Polyethylene terephthalate
PPI	Producer Price Index
PVC	Polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RDF	Refuse-derived fuel
RMP	Residential mixed paper
RPF	Recyclables processing facility
SWANA	Solid Waste Association of North America
UBC	Used beverage cans (aluminum)
WTE	Waste-to-energy