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Air Pollutant Emission Standards and Guidelines for Municipal Waste Combustors:

Economic Analysis of Materials Separation Requirement

Emission Standards Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
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CHAPTER 1
INTRODUCTION

The New Source Performance Standards and Emission Guidelines for municipal waste combustors (MWCs) mandate separation and removal of 25 percent of municipal solid waste prior to combustion in an MWC. Specifically, credit is given for separation of one or more of the following materials:

- Paper and paperboard
- Ferrous and nonferrous metals
- Glass
- Plastics
- Household hazardous wastes
- Household batteries
- Motor vehicle maintenance materials (used oil, tires, and batteries)
- Yard waste and leaves

The separation requirement mandates not only the removal of 25 percent (calculated as annual average by weight) of municipal solid waste, but also the separation of lead-acid batteries heavier than 4.4 pounds. In addition, the separation requirement allows a maximum of 10 percentage points credit for yard waste and leaves.

Using the example of a household, the flowchart in Figure 1-1 shows the destinations of waste and recoverable materials. Notice that several paths lead to landfills and MWCs. The stated intent of the materials separation requirement is to dramatically alter the flow of municipal solid waste (MSW), diverting it from MWCs. Although diversion of MSW from MWCs is itself beneficial, recycling must occur to obtain the additional benefits of increasing the supply of materials that are substitutes for virgin paper, metals, glass, and plastic.

Clearly, recycling is essential for reducing the quantity of combusted or landfilled solid waste. Typically, a residential recycling program requires households to separate recyclables from refuse and to set them out for curbside pick-up, a collection system (i.e., trucks and crew) in addition to the ordinary refuse collection system, and a

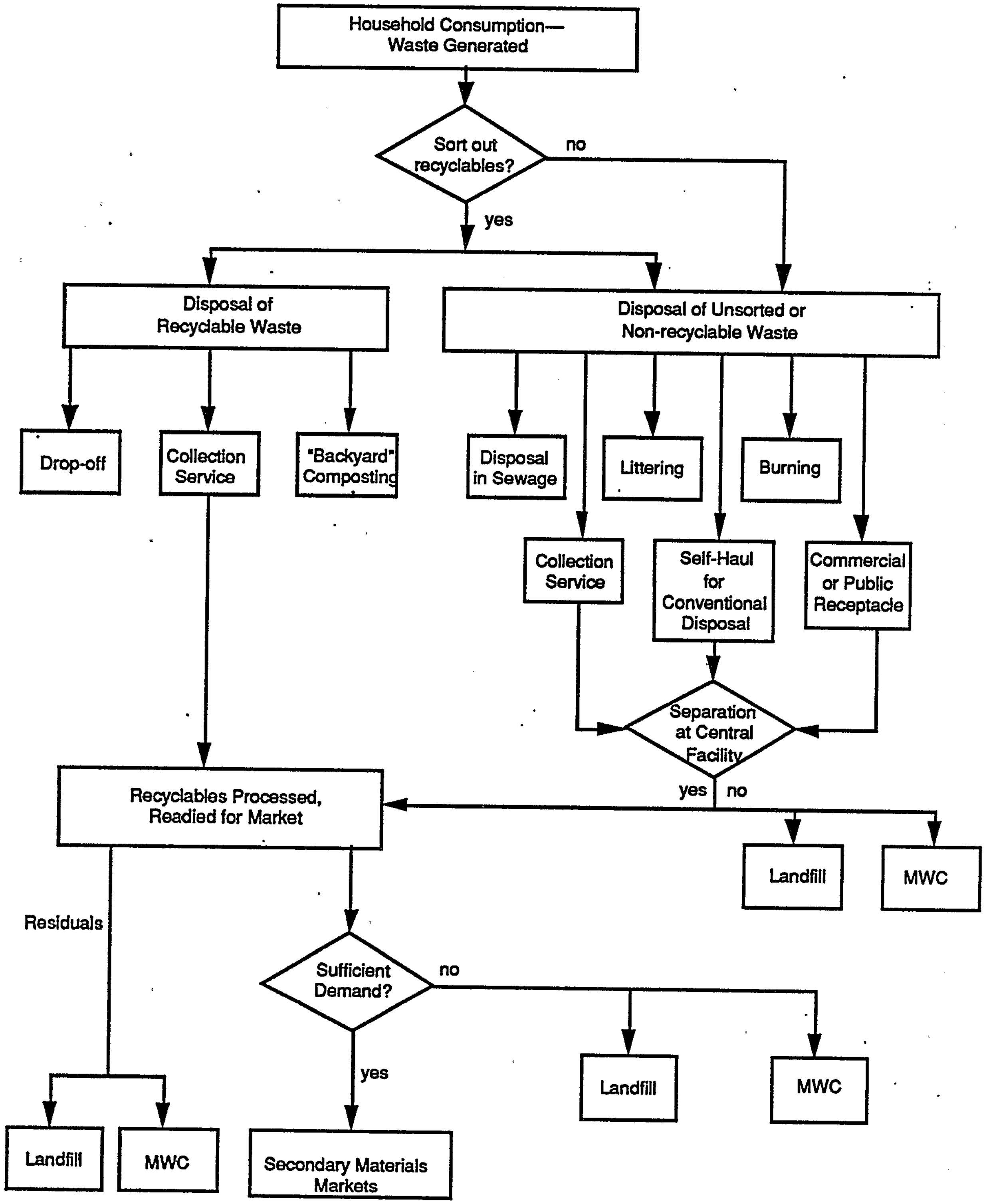

Figure 1-1. Household Solid Waste Flows

facility that readies recyclable materials for market. Recycling requires a fundamental change in the ways that households and municipalities manage waste.

This study investigates the cost and performance of the recycling programs that communities may rely on to comply with the materials separation requirements. It addresses the following specific questions:

- How will increased separation be carried out?
- How much will the requirement increase materials separation?
- How will the requirement affect solid waste flows to MWCs and landfills?
- How will the requirement affect prices and quantities in the markets for secondary materials?
- What is the cost of increased separation?

CHAPTER 2
MATERIALS SEPARATION AND RECYCLING PROGRAMS: PREDICTING THE IMPLEMENTATION OF THE MATERIALS SEPARATION REQUIREMENT

"Materials separation" refers to the first phase of recycling—diverting materials from the combusted waste stream. "Recycling" requires two additional phases: preparing the separated materials for market, and manufacturing new products with these materials. These phases lead logically from one to another, and all three are required for recycling to occur (U.S. Congress, 1989). Traditionally, some materials are not recycled after separation because they do not meet market specifications or because the separated materials are not in demand due to a temporary surplus of the material in secondary materials markets.

One goal of the New Source Performance Standards (NSPS) and Emission Guidelines (EG) is to have communities with municipal waste combustors (MWCs) interpret the materials separation requirement not only as a requirement to divert waste from an MWC but also as part of a waste management system that involves recycling the diverted materials. This particular goal is consistent with the Agency's announced objective of increasing recycling by governments, individuals, and corporations (U.S. EPA, 1989b, p. 24).

The regulated communities may employ a large variety of materials separation programs to comply with the proposed regulation. Because of the diversity across the regulated communities, all communities will probably not pursue the same program. They are more likely to tailor programs to their local situations. A number of program characteristics may influence the nature and costs of a community's response to the proposed regulation. Most important among these characteristics are the materials targeted for separation and the place of separation.

Materials differ according to their representation in the municipal solid waste (MSW) stream and their market value. MSW includes all nonhazardous wastes from household, institutional, commercial, municipal, and industrial sources (U.S. EPA, 1988c). Approximately 143 million Mg of MSW were generated in the United States in 1986 (Franklin Associates, 1988).

The NSPS and EG express the separation requirement in terms of the proportion by weight of the combusted waste stream, but it is incorrect to conclude that the form of the requirement implies that the heaviest factions of the waste stream are the best targets for separation. Because separation will impose costs, the opportunity may exist to partially or completely offset these costs if the separated material can be sold in secondary materials markets. The problem faced by municipalities is that some of the highest share components of the waste stream have little or no value to offset their separation costs (e.g., yard wastes) while other fractions have a high value but represent only a small share of the waste stream (e.g., aluminum).

A second consideration faced by the regulated communities is where to separate materials from the waste stream. Centralized separation, at one extreme, would require generators to discard mixed wastes, which would be collected and subsequently separated and processed at a central facility. This method calls for the explicit expenditure of resources by the community to build and operate these materials recovery facilities. At the other end of the spectrum, generators would be required to separate certain fractions of their solid waste stream and place them at the curbside for collection or take them to a centralized drop-off location. This type of materials separation requires the implicit expenditure of resources by households.

Some of the key recycling program collection and processing characteristics are outlined in this chapter along with examples of actual communities using each program. These program characteristics are subsequently used to develop a set of model programs designed to represent communities' responses to meeting the materials separation requirement.

Section 2.1 first draws a distinction between materials separation and recycling and then describes several materials separation and collection strategies currently in use across the nation.

Section 2.2 establishes the baseline level of recycling for residential curbside collection programs as well as for commercial and institutional collection sources. (See Appendix A for information about state and national recycling efforts.)

Section 2.3 presents several case studies of municipally run recycling programs. Several characteristics of these programs are compared, including cost, size of population served, and collection features.

Section 2.4 describes the model curbside collection programs developed for this study. The two types of model collection programs discussed in this section are the strategies most likely to be implemented in response to the NSPS and EG. Section 2.4 also provides the estimated household participation rates for each model program and the projected capture rates for each target material (i.e., steel cans, aluminum cans, newspapers, yard waste, glass containers, and high density polyethylene (HDPE) and polyethylene terephthalate (PET) plastic containers).

2.1 OVERVIEW OF MATERIALS SEPARATION AND RECYCLING

This section first draws a distinction between materials separation and recycling and then describes several materials separation and collection strategies currently in use across the nation. A primary behavioral assumption is that materials separation is perceived, not only as a method of diverting waste from an MWC, but as part of a materials management system. Shifting to a materials management concept requires thinking of MSW in terms of its components as individual resource streams rather than as an indistinguishable mixture (Waird, 1990).

2.1.1 Differentiating Materials Separation from Recycling

Recycling consists of three different phases: separating and collecting target materials, preparing those materials for market, and actually manufacturing new products with recyclable materials. All of these phases are related and required for recycling to occur. Recycling does not occur unless the collected recyclable materials are made into a product that is actually used (U.S. Congress, 1989).

Materials separation, on the other hand, refers simply to collecting and preparing target materials for market. Some materials will not be recycled after separation because either the materials do not meet market specifications or no market demand for the materials exists.

Therefore, materials separation and recycling differ in one important respect: what happens to the separated materials after they are collected and processed. This study focuses on the collection and preparation phases of recycling and materials separation.

2.1.2 Materials Separation and Recycling Programs

Community managers must consider a plethora of issues when designing a materials separation program, including solid waste generation rates, population served, public convenience, collection characteristics, number of target materials, availability of disposal facilities, market requirements, distance to market, program cost, space needs, administrative roles and responsibilities, personnel needs, application of economic incentives/disincentives, and degree of community support (O'Leary and Walsh, 1988 and The Minnesota Project, 1987).

Several materials separation and recycling program strategies are described below. Each strategy can be classified into one of two groups:

- relies exclusively on a centralized materials recovery facility or
- requires household separation (possibly augmented with curbside separation by collection crews).

Each strategy is illustrated with an example of a currently operating city program.

2.1.2.1 Centralized Separation

With centralized separation, commingled (mixed) materials picked up by curbside programs are sent to a central material recovery facility (MRF). At the MRF, materials in the incoming commingled stream are separated and processed into marketable recyclables. A MRF can stand alone or it can be incorporated into transfer stations, composting facilities, or the front end of waste-to-energy projects (Berenyi, 1990).

The capital intensity of MRFs can vary considerably, as can the type of waste stream they can process. A MRF can use complex machinery to separate various elements of value from the waste steam, or it can rely largely on human labor to manually pick through the wastes. The incoming waste stream can range from a load of garbage dumped onto a tipping floor to a shipment of highly source-separated recyclables (*Biocycle Journal of Waste Recycling*, 1990).

MRFs can be designed to recover a variety of materials. The most common materials cited are steel cans, clear glass, brown glass, green glass, aluminum, bi-metal cans, newspaper, HDPE plastics, and PET plastics. On average, about 10 percent of a MRF's daily tonnage ends up as nonrecyclable residue (Berenyi, 1990). This residue is a mixture of grit and contaminated paper and is usually disposed of but is sometimes composted.

The MRF at Johnston, Rhode Island (see Table 2-1), is an example of a MRF that accepts source-separated commingled recyclables (Berenyi, 1990). Crestwood, Illinois, operates a MRF that accepts about 400 tons of unseparated MSW (garbage) a day. Figure 2-1 illustrates the materials separation process used by the Crestwood facility (Radian Corporation, 1990).

2.1.2.2 Household Separation

Household separation requires residents to separate target recyclables from the rest of the garbage. These recyclables are then set out for curbside collection as part of the single-stream separation, two-stream separation, and multiple-stream separation programs or taken to a drop-off center by the resident.

Single-Stream Household Separation. Single-stream household separation refers to a separation strategy that asks residents to provide commingled (mixed) recyclables (excluding compostable material) in a single container. For example, in one area of Seattle residents commingle all containers and old newspapers. Commingled set out is the most convenient strategy for residents; however, because the markets that purchase commingled materials are typically scarce, post-resident sorting is often necessary (*Biocycle Journal of Waste Recycling*, 1990). Post-resident sorting can be done either at the curbside or at a centralized separation facility (i.e., a MRF).

With curbside sorting the collector picks up the home storage container (containing a mixture of recyclables) and sorts the materials truckside into discrete fractions representing the various salable commodities. Curbside sorters perform a quality control function by rejecting nonrecyclables (which are simply left in the container). Therefore, depending on the training and performance of the collector, the separated materials are close to market specifications.

TABLE 2-1. JOHNSTON, RHODE ISLAND, MATERIALS RECOVERY FACILITY (MRF)

Name: Johnston MRF
Location: Johnston, RI
Status: Operational
Start-up Date: 5/89
Geographic Area: Northern Rhode Island (10 cities and towns; 1/3 of RI's population)

Technical Specifications

Degree of mechanization:	High
Design capacity (TPD):	130
Building size (ft^2):	40,000
Residue (TPD):	13.0
Degree of pre-sorting:	None
Materials commingled:	42%
Materials source separated:	58%
Residue/TPD design ratio:	0.10

Operating History

Days operation/week:	5
Shifts/day:	2
Hours/shift:	8
Days operation/year:	250
Annual tons processed (yr):	36,000 (89)
Total FTE employees:	19

Materials Recovered

Specific materials recovered:
newspaper, cardboard, glass (clear, brown, green), aluminum, tin and bi-metal cans, PET and HDPE plastics

Materials	Tons per day
Newspaper	55.0
Mixed recyclables	75.0

Costs

Capital Costs

Original capital costs (yr):	$4,150,000 (89)
Adjusted capital costs (yr):	$4,150,000 (89)

Operation and Maintenance Costs

Annual O&M without debt service (yr):	$1,054,000 (89/90)

Notes: High-tech Bezner system separates glass from aluminum and plastics; also uses magnetic separator. Glass and plastics hand-sorted. New England CR Inc. has three-year contract.
Source: Berenyi, 1990.

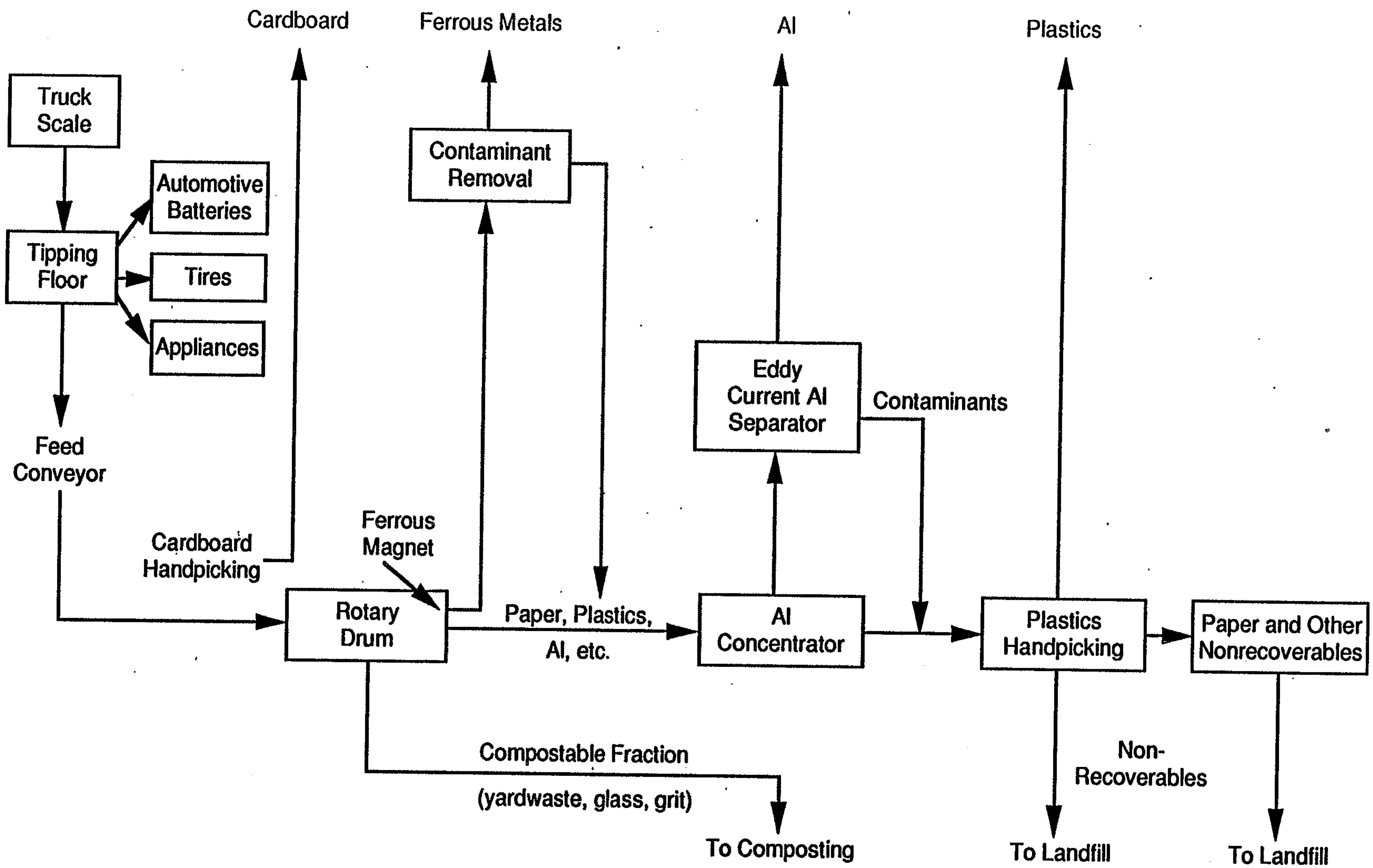

Figure 2-1. Schematic Diagram of Materials Separation Process at Crestwood, Illinois.
Source: Radian Corporation, 1990. Figure 4-1.

Curbside separation requires less household effort and storage of materials for collection than multiple-stream separation and is easy to change as the program grows (or as markets fluctuate) without households having to change their separation behaviors. Probably the biggest advantage of curbside sorting is that it enables the community to sell higher quality recyclables without having to develop and pay to operate expensive processing facilities (*Biocycle Journal of Waste Recycling*, 1990).

One community that operates a successful program in which collectors sort at the curb is Anne Arundell County, Maryland. The contract collector for the county completes routes of slightly over 1,000 homes a day. Collectors make between 450 and 600 stops per day where they sort and load the materials into the collection truck. They separate materials into five compartments: three for different colors of glass, one for mixed cans (aluminum and ferrous), and one for old newspapers (*Biocycle Journal of Waste Recycling*, 1990).

In the south side of Seattle, Washington, commingled recyclables are separated at a MRF. Recyclable materials are collected in a rear-loading truck and delivered to an 800,000 square foot facility, which combines mechanized and hand-sorting techniques. The local collection company provides each resident one, large, 90-gallon wheeled container in which the resident commingles all target materials for collection once per month. Residents can request a 60-gallon container (Allan, Platt, and Morris, 1989).

Two-Stream Household Separation. In two-stream household separation, households put commingled target recyclables into one container and place stacked and/or bundled paper near the container.

Haddonfield, New Jersey, is an example of a community that uses two-stream household separation. The borough of Haddonfield is a residential suburb of Camden, New Jersey, and Philadelphia, Pennsylvania. In March 1985, participation in the municipal curbside recycling program became mandatory. In May 1986, the Camden County Intermediate Processing Facility (CCIPF) opened to accept all glass and metal food and beverage containers. The new facility accepts commingled tin, steel, and mixed metal for recycling. The Borough now has a stable market, and the County separates, processes, stores, and markets the materials. The Borough considered collecting plastic containers, but found this activity to be prohibitively expensive to implement. Residents commingle recyclables into one or more containers, stack old newspapers in paper bags or bundle them separately, and flatten corrugated cardboard. Recyclables are collected with two 1-ton pick-up trucks, each pulling a 12-cubic yard trailer with five compartments. Newspapers are unloaded from the trailer into the dumpster at the Borough yard two or three times per day. The trucks haul bottles and cans to the CCIPF (Allan, Platt, and Morris, 1989).

During a strong enforcement program, driver records showed that only about 5 percent of the 4,400 households in Haddonfield never put out any recyclable materials. Some households (particularly senior citizens) do not put materials out weekly, but do so biweekly or monthly. Some households share containers (Allan, Platt, and Morris, 1989).

Multiple-Stream Separation. Multiple-stream separation requires residents to separate recyclables into at least three divisions: for example, one for glass containers mixed with metal cans, a second for mixed paper, and a third for newspaper. As the City of Portland's program illustrates (see below), however, the level of separation can be increased considerably. The multiple-stream separation strategy is more effective than the other two separation strategies in reducing the contamination of one recyclable waste stream by another. Even with multiple-stream separation, however, some materials preparation is often necessary to meet the needs of buyers.

With multiple-stream separation households perform much of the labor of sorting and bear the implicit costs of this effort. The municipality's explicit costs may be less than with less complete separation. Typically the municipality is able to obtain a higher price for well-separated materials compared with commingled recyclables. One disadvantage of multiple-stream separation is its high dependency on public participation to prepare materials properly. Another disadvantage of multiple-stream (and two-stream) separation is the need to buy expensive, specialized equipment, such as a compartmentalized collection vehicle (U.S. Congress, 1989).

The curbside collection program in the north section of Seattle, Washington, is operated by Recycle America, a subsidiary of Waste Management, Inc., and serves 65,000 households. Residents are provided three stackable containers: one for glass, aluminum, and tin cans and containers; a second for mixed scrap paper; and a third for old newspapers. Any cardboard is placed next to the containers. A compartmentalized recycling truck collects recyclable materials weekly. Recycle America owns and operates a processing facility that separates glass, aluminum, and tin with a combination of hand and mechanical sorting (Allan, Platt, and Morris, 1989).

The City of Portland, Oregon, implemented a multiple-stream separation program on June 1, 1987. Waste haulers are required by the city to offer their customers a minimum service level of weekly curbside collection of old newspapers and monthly curbside collection of old newspapers, glass bottles, tin cans, corrugated cardboard, aluminum, ferrous metals, non-ferrous metals, and used motor oil. Residents are required to set out seven separate bins and bundles of recyclables as follows:

- Newspapers—bag, box, or bundle tightly with string.
- Glass jars and bottles—rinse and sort by color.
- Used motor oil—pour into leak-proof plastic or metal container with a screw-on lid.
- Corrugated cardboard—flatten and bundle.
- Tin cans—remove labels, cut out both ends, then rinse and flatten.
- Aluminum—rinse cans, food trays, and foil.
- Other metals—prepare scraps so they are less than 30 inches long and free of rubber, plastic, or other foreign materials.

In addition, commercial customers must prepare paper as follows:

- High grade paper—separate white, colored, and green-striped computer papers.

Drop-Off Centers. Drop-off centers require residents to carry their recyclables to a central collection point. Currently they are the most common form of community-based recycling. Recyclables are stored at the centers until being transported to a processing facility (only very limited materials processing occurs at drop-off centers).

Convenient, safe access and quality control are the keys to a successful drop-off center. Program coordinators generally agree that the most desirable drop-off sites are located within three to five miles of home. Shopping centers, grocery stores, schools, and churches are frequently chosen sites (*Biocycle Journal of Waste Recycling*, 1990).

Drop-off programs can be especially useful in communities just becoming involved in recycling because the programs are fairly inexpensive to operate. In areas with low waste disposal costs, drop-off programs may be more economically feasible than curbside programs. Rural areas are well-suited for drop-off programs because low population densities make curbside collection impractical. At the other end of the scale, high-density population areas (such as multi-family residences) are also good locations for drop-off programs (*Biocycle Journal of Waste Recycling*, 1990). Wherever drop-off centers are placed, care must be taken to ensure the collection of high-quality materials.

Most drop-off programs do not provide the same level of service as curbside collection programs; however, drop-off programs have proven to be effective as adjuncts to curbside programs because adding drop-off sites to a curbside program may improve the program's overall convenience (especially for residents in nearby neighborhoods that are not included in the recycling program). For example, when a pilot curbside collection program started in Durham, North Carolina, the material collected at the drop-off center actually increased (*Biocycle Journal of Waste Recycling*, 1990). Drop-off facilities also can expand the collection of target materials by providing a place to receive hard-to-collect materials (such as plastics, corrugated cardboard, batteries, and motor oil).

Although drop-off centers are common components of curbside programs, they are excluded from the model programs (see Section 2.4 below) because of the difficulty of estimating the participation and capture rates for these facilities. Another reason is that quality control—likely to be critical in the future—is best achieved through curbside programs per se.

2.1.2.3 Composting

Composting is the natural, aerobic degradation of organic material (such as grass clippings, leaves, brush, and tree prunings). It can be carried out with as little, or as much, intervention and attention as the composter desires. Some communities give residents two options for composting their yard wastes: backyard composting, or source separation followed by centralized composting (Taylor and Kashmanian, 1988).

The choice of collection method depends on cost, convenience, household participation, and amount and type of yard wastes separated and collected (Taylor and Kashmanian, 1988). Table 2-2 shows the various separation and collection methods used in eight currently operating composting programs. Yard waste may be bagged, placed in a container, left at the curbside, or dropped off at a central collection site. Depending on the collection method and the level of separation required, pre-processing may be necessary. For example, non-biodegradable plastic bags need to be opened and brush may need shredding. Collection service varies from weekly to seasonally, depending on the type of yard waste composted and the collection equipment used (e.g., curbside vacuums are usually used primarily in the fall). All yard waste is collected separately from normal trash (Taylor and Kashmanian, 1988).

TABLE 2-2. YARD WASTE SEPARATION AND COLLECTION METHODS

City or County	State	Mandatory program? (Y/N)	Collection Method[a]	Frequency of Collection[b]	Collection Seasons[b]	Means of Raising Awareness and Support for the Program in the Community
Davis	CA	N	backyard	n/a	Sp, Su, F, W	public education
		N	curbside—claw	1/week	Sp, Su, F, W	public education
East Tawas	MI	N	curbside—plastic bag resident drop-off	1/week	Sp, F	newspaper ad
Montgomery Co.	MD	N	curbside—vacuum	1/Sp, 2/F	Sp, F	pickup schedule signs
Omaha	NB	N	curbside—wheeled bin and degradable bag	1/week	Sp, Su, F	neighborhood association
		c	landscaper drop-off	n/a	Sp, Su, F	
Seattle	WA	N	backyard	n/a	Sp, Su, F, W	hotline, public education
		N	resident drop-off	n/a	Sp, Su, F, W	
		N	landscaper drop-off	n/a	Sp, Su, F, W	
Wellesley	MA	N	backyard	n/a	Sp, Su, F, W	public ed, newspaper, bill stuffers
		N	resident drop-off	n/a	Sp, Su, F, W	public ed, newspaper, bill stuffers
		N	landscaper drop-off	n/a	Sp, Su, F	word-of-mouth
Westfield	NJ	Y	curbside—front loader	2/F	F	hotline, newspaper ad
		Y	resident drop-off	n/a	Sp, Su, F	newspaper ad, mailings
		Y	landscaper drop-off	n/a	Sp, Su, F	newspaper ad
Woodbury	MN	N	backyard		Sp, Su, F	public education
			curbside—degradable bag	1/week	Sp, Su, F	free bags yr 1, mailings

Notes: [a] "backyard" refers to backyard composting.
[b] Sp - spring, Su - summer, F - fall, W - winter: (2/F - 2 collections per fall,etc.)
[c] information not available.
Y/N: yes/no
n/a: not available for collection.
Source: Taylor and Kashmanian 1988, Table 4.

The nation has at least 1,000 yard waste composting facilities, and many more are expected to begin operation in response to state and local mandated source separation laws. For example, the City of Seattle requires residents to separate yard waste from household trash. Yard waste, representing 30 percent of the city's residential waste stream, is collected for a fee. The fee serves to encourage backyard composting. The utility also sponsors a backyard composting education program run by a local, nonprofit organization of urban gardeners (Allan, Platt, and Morris, 1989). Despite the number of composting facilities, yard waste continues to be a substantial component of landfilled solid waste.

2.2 BASELINE LEVELS OF RECYCLING

Some communities with MWCs already have recycling programs. Others have plans to implement such programs for residential or commercial and institutional generators. The NSPS and EG will give full credit for the material collected in existing recycling programs toward the 25 percent requirement. Therefore, the increment in materials separation required for compliance will be less for communities with existing recycling programs than for communities without recycling programs. It is not possible to identify every community that is currently achieving a 25 percent materials separation level as defined in the NSPS and EG, but it is possible to identify the states that have mandated recycling goals of at least 25 percent to be achieved in the near future.

New Jersey, which set a 1988 deadline for 25 percent recycling, is the only state to have reached its deadline for complying with its mandated recycling goal. Other states and areas that have set deadlines for achieving their goals between now and 1995[1] include Connecticut, the District of Columbia, Florida, Louisiana, Minnesota, North Carolina, Ohio,[2] Virginia, and Washington (Glenn, 1990). Because they will not need to develop new materials separation programs, these states are omitted from the analysis to determine the cost of implementation of the materials separation regulation on a national basis (see Chapter 4).

2.3 CASE STUDIES AND SURVEYS OF RECYCLING PROGRAMS

Communities across the country are recognizing recycling as an effective alternative to the disposal of municipal solid waste because it reduces the amount of

[1] This year is the deadline for compliance with the materials separation requirement.
[2] Akron and Columbus, Ohio (cities with large waste-to-energy facilities), already operate front-end separation and pilot curbside programs in some areas.

waste to be landfilled or incinerated. In fact, six of the nation's ten largest cities (Chicago, Los Angeles, New York, Phoenix, Philadelphia, and San Diego) have curbside collection programs. Three others (Houston, San Antonio, and Dallas) have programs in preliminary stages. In addition, municipalities around the country operate more than 1,000 curbside recycling programs (National Solid Wastes Management Association, 1989). Some nonprofit organizations and private enterprises also conduct collection programs.

Implementing a recycling program presents a number of problems, challenges, and opportunities for municipalities and recycling companies. Solid waste management planners must consider what to recycle, how to collect recyclables, how to increase participation rates and maximize materials recovery, how to determine costs, and how to market the recyclables.

This section describes a sample of the wide variety of municipally run curbside collection programs to illustrate possible designs for recycling programs. It would be ideal to compare the costs and levels of materials recovery, and to determine how they vary with density, size, and waste composition. The lack of reliable data, in part due to the lack of a standard definition for the term "municipal solid waste," makes such comparisons difficult. Table 2-3 gives examples of different definitions of municipal solid waste used in different programs across the country

Careful consideration of the economic data and tonnage data provided in surveys of curbside programs indicates that any detailed statistical analysis of these programs would be handicapped by the information that communities provide on how much waste they generate, how much of this waste is recovered, and how much it costs to do so. Therefore, the available data are most appropriately used to make broad inferences about the relative popularity of different types of programs, target materials, the point where materials separation takes place, and other attributes of the programs that will be operated in response to the NSPS and EG.

TABLE 2-3. DEFINITIONS OF MUNICIPAL SOLID WASTE

Program	Definition
Barrington, RI	Refuse generated by residents through their daily course of living: includes school refuse, but does not include waste from contractors or businesses.
Deschutes County, OR	Everything delivered to the County's five landfills and one transfer station, including household, commercial, industrial, and demolition debris.
Hamburg, NY	Mixed waste from households not including construction and demolition debris, bulky waste, or white goods.
Hempstead, NY	All materials set out for collection, including bulk items and recyclables.
Longmeadow, MA	Nonresidential with the exception of two elderly housing projects and a nursing home; includes shopping areas.
Mecklenburg, NC	Whatever is collected by the municipality—residential waste and small businesses.
Metro Toronto, ONT	Domestic waste from residences and apartments and waste collected by municipal forces including light commercial, street sweepings, catch basin cleanings, ash, sewage sludge, park wastes, waste from municipal offices and waste from libraries, etc.
Montclair, NJ	Type 10 refuse as defined by the State of New Jersey and collected by the Town.
Newport, RI	Waste generated by city residences and certain municipal buildings: also includes litter barrels.
Orlando, FL	All putrescible and nonputrescible solid waste, except body waste, including garbage, rubbish, ashes, street cleanings, dead animals, or discarded materials of any kind that tend to decay or putrefy.
Prairie Du Sac, WI	Refuse accumulation of animals, fruit or vegetable matter, liquid or otherwise, that attends the preparation, use, cooking, dealing in, or storage of meat, fish, fowl, fruit or vegetables.
Sarasota, FL	Residential and yard waste.
Sauk County, WI	All the commercial and post-consumer materials requiring disposal.
Seattle, WA	All waste, except demolition debris, generated within Seattle's city limits.
Sunnyvale, CA	Commercial and residential waste.
Wilkes-Barre, PA	Waste generated by people, but not household furnishings or appliances.
Woodbury, NJ	Garbage, building materials, contaminated papers, appliances.
Upper Arlington, OH	Household refuse and yard waste.

Source: Snow, 1989, Table 3.

2.3.1 Case Studies

This section compares performance, conditions of service, and other characteristics of 13 municipally run recycling programs. The comparison uses the data contained in *Beyond 25 Percent: Materials Recovery Comes of Age*. The authors of that study conclude, in part, that

> Extensive materials recovery in peacetime is so new that most programs still lack basic quantitative data. Five years ago most communities had no idea how much waste they generated. Because of their expectations for incineration, communities that did conduct studies tended to divide their waste streams into only two primary categories; combustibles and noncombustibles. Even today very few communities have information on the amount of garbage generated by the commercial or industrial sectors, or of white goods, or even of yard waste.
>
> Economic data are also inadequate. Communities whose recycling programs are separate from regular pick-up may have relatively good cost figures. But, in communities where recycling is part of the municipal collection services, or where private collectors pick up recyclable items from the commercial or residential sector as part of their collection contracts, economic data are scarce and often unreliable. (Allan, Platt, and Morris, 1989, page 3).

Table 2-4 compares information from the 13 case studies. The communities range in size from 1,100 households in Prairie Du Sac, Michigan, to 150,000 households in Portland, Oregon. Nine of the communities have fewer than 40,000 people. This sample is fairly representative of national demographics—thousands of cities have populations of 5,000 to 40,000, compared with only a few hundred with populations over 100,000. Most of the surveyed communities are achieving greater than 75 percent participation. Six areas report that over 90 percent of households participate. The programs have a nine-to-four split of voluntary to mandatory participation, respectively (Allan, Platt, and Morris, 1989).

All of the communities collect old newspapers, corrugated paper, glass containers, aluminum cans, and yard waste. All but three of the communities collect ferrous cans, and only three collect plastic containers (i.e., PET and/or HDPE). One community has single-stream set out, eight communities have two-stream set out, and four communities have multiple-stream set out (Allan, Platt, and Morris, 1989).

Perkasie, Pennsylvania, and West Linn, Portland, use per-bag disposal fee programs to encourage waste reduction and provide a direct economic incentive to recycling. West Linn residents are charged by volume (per 30-gallon can) of waste generated. Perkasie residents can purchase large bags with the capacity to hold up to 20 pounds for $1.50 and small bags with capacity to hold up to 20 pounds for $0.80 (Allan, Platt, and Morris, 1989).

TABLE 2-4. COMPARISON OF RECYCLING PROGRAMS

City	State	Population	Number of Households	Mandatory Participation	Unit Pricing	Setout Method	Participation Rate
Longmeadow	MA	15,971	5,400	Y	N	multiple-stream	90
West Linn	OR	13,000	4,700	N	Y	multiple-stream	61
Montclair	NJ	38,600	14,500	Y	N	two-stream	80
Prairie Du Sac	WI	2,289	1,100	Y	N	two-stream	95
Hamburg	NY	10,500	3,350	Y	N	two-stream	98
Islip	NY	300,000	77,000	Y	N	single-stream	95
East Lyme	CT	14,830	5,375	Y	N	two-stream	85
Minneapolis	MN	370,000	124,000	N	N	multiple-stream	45
Woodbury	NJ	10,500	3,500	Y	N	multiple-stream	85
Haddonfield	NJ	12,337	4,400	Y	N	two-stream	95
Perkasie	PA	6,500	2,600	Y	Y	two-stream	93
Lane County	OR	269,500	30,000	N	N	multiple-stream	25
Portland	OR	471,000	150,000	N	N	two-stream	25

Source: Allan, Platt, and Morris, 1989.

2.3.2 National Solid Wastes Management Association (NSWMA) Survey

The National Solid Wastes Management Association (NSWMA) conducted a survey in 1989 of 24 household curbside collection programs. The survey was designed to compile a detailed picture of curbside collection operations across the nation. Table 2-5 outlines the basic characteristics of each program surveyed. The programs range in size from 1,100 households in Prairie Du Sac to 250,000 households in Metro Toronto, Ontario. Target materials include old newspapers, corrugated cardboard, mixed paper, aluminum cans, glass, plastic bottles, leaves, tin cans, white goods, and waste oil. The programs have a 12-to-11 split of voluntary versus mandatory participation, respectively (Sauk County, Wisconsin, has both classifications of participation). Participation rates in mandatory programs are, on average, twice as high as voluntary programs (Snow, 1989).

2.4 MODEL PROGRAMS

The decisions made in developing the model programs listed below are based on data from the Institute for Local Self-Reliance's *Beyond 25 Percent: Materials Recovery Comes of Age*, the 1989 NSWMA survey of local programs, current literature, as well as discussions with state environmental offices, local program operators, and curbside recycling program consultants. Communities can choose from literally hundreds of combinations of specific program parameters when planning curbside collection. The model programs are designed to be plausible and to represent the range of likely responses of communities to the regulation.

Presumably, none of the modeled programs affect the diversion rate of either white goods (e.g., refrigerators, stoves) or stumps; it is also assumed that the cost of collecting and processing these things is unaffected by the materials separation requirement. The analysis of the collection and processing of household batteries, household hazardous waste, and motor vehicle maintenance materials is beyond the scope of this study. The modeled programs encompass only the diversion and processing of old newspapers, certain types of containers, and the lighter fractions of yard waste (i.e., leaves, grass, and brush).

2.4.1 Key Elements of Materials Separation Model Programs

Each model program is defined by the following characteristics:

- target materials,
- point where materials separation takes place,
- imposition of mandatory participation ordinances,
- quality of promotional services (public advertising and educational programs),

TABLE 2-5. BACKGROUND INFORMATION FROM THE NATIONAL SOLID WASTES MANAGEMENT ASSOCIATION SURVEY

Start Up Program	Year	Population Served	Households Served	Voluntary or Mandatory?	Frequency of Collection	Same Day as Refuse Collection?	Frequency of Refuse Collection
Barrington, RI	1972	17,700	5,600	mandatory	monthly	yes	once/week
Broome County, NY	1987	37,200	13,500	voluntary	weekly	yes & no	once/week
Bucks County, PA	1989	115,000	28,500	mandatory	weekly	yes	twice/week
Deschutes County, OR	1985	25,000	10,000	voluntary	weekly, monthly, cans & bottles	yes	once/week
Hamburg, NY	1981	11,500	3,350	mandatory	weekly	yes	once/week
Longmeadow, MA	1984	15,971	5,672	mandatory	weekly	yes	once/week
Mecklenburg County, NC	1987	40,000	9,166	voluntary	weekly	yes	twice/week
Metro Toronto, ONT	1988	800,000	250,000	voluntary	weekly	yes	twice/week
Montclair, NJ	1971	38,600	14,500	mandatory	biweekly	no	twice/week
Newport, RI	1988	24,200	9,700	mandatory	weekly	yes	twice/week
Onondaga County, NY	1988			voluntary; will be mandatory	weekly	yes	once/week
Orlando, FL	1987	151,654	38,114	voluntary	weekly	yes	twice/week
Prairie Du Sac, WI	1982	2,290	1,100	mandatory	weekly	no	once/week
Roanoke, VA	1987	pilot area	1,000	voluntary	weekly	yes	once/week
St. Cloud, MN	1983	43,000	10,107	mandatory	monthly	no	once/week
Sarasota, FL	1988			voluntary	weekly	yes	twice/week

continued

TABLE 2-5. BACKGROUND INFORMATION FROM THE NATIONAL SOLID WASTES MANAGEMENT ASSOCIATION SURVEY (CONTINUED)

Start Up Program	Year	Population Served	Households Served	Voluntary or Mandatory?	Frequency of Collection	Same Day as Refuse Collection?	Frequency of Refuse Collection
Sauk County, WI	1979	12,000	3,000	varies	weekly	varies	once/week
Seattle, WA	1988	500,000	147,000: eligible; 94,101: service	voluntary	1/2 weekly: 1/2 monthly	varies	once/week
Sunnyvale, CA	1982	114,000	28,000	voluntary	weekly	yes	once/week
Upper Arlington, OH	1988	36,000	12,000	voluntary	weekly	yes	once/week
Wilkes-Barre, PA		50,500	13,500	mandatory	weekly	no	once/week
Woodbury, NJ	1981	10,353	4,200	mandatory	weekly	no	once/week
Somerset County, NJ	1986	220,000	80,000	mandatory	biweekly	varies	varies
Hempstead, NY	1987	55,000	14,500	voluntary	weekly	yes	twice/week

Source: Snow, 1989, Table 1.

- application of unit pricing incentives,
- type of post-collection processing,
- participation rates, and
- capture rates.

Table 2-6 lists the characteristics that define each program. These characteristics are described below.

2.4.1.1 *Target Materials*

As shown by existing programs, the level of materials recovery and recycling is directly related to the number of materials targeted for separation from the waste stream. All programs are expected to target steel cans, aluminum cans, old newspapers, yard waste, glass containers, and PET and HDPE plastic containers.

2.4.1.2 *Point of Separation*

Point of separation refers to where the recyclables are separated from the municipal solid waste stream. All the model programs rely on household source separation with curbside pick-up. A program in which the municipal solid waste stream is sent unseparated to a MRF for processing was not modeled because it is an unlikely response to the regulation. Such programs require expensive facilities that communities are unlikely to finance. In addition, these facilities yield highly contaminated materials, imposing a penalty on sales.

2.4.1.3 *Mandatory Participation Ordinances*

Municipalities in states with mandatory recycling laws are often required to adopt mandatory recycling ordinances. In fact, a municipality's power to adopt a mandatory recycling ordinance depends on the existence of some state legislation authorizing the municipality to do so (*Biocycle Journal of Waste Recycling*, 1990). The models in this study include both communities with and without mandatory participation ordinances. As reflected in the models, mandatory participation does not ensure total participation.

TABLE 2-6. KEY ELEMENTS OF MATERIALS SEPARATION MODEL PROGRAMS

	Two-Stream Programs		Multiple-Stream Programs				
	Option		Option				
	1	2	1	2	3	4	MS
Characteristic							
Target materials							
Steel cans (capture rate = 60%)	1	1	1	1	1	1	1
Aluminum cans (capture rate = 60%)	1	1	1	1	1	1	1
Newspapers (capture rate = 80%)	1	1	1	1	1	1	1
Yard waste (capture rate = 80%)	1	1	1	1	1	1	1
Glass containers (capture rate = 65%)	1	1	1	1	1	1	1
PET & HDPE plastic containers (capture rate = 65%)	1	1	1	1	1	1	1
Recyclables separated by households with curbside pick-up service	1	1	1	1	1	1	1
Partially commingled recyclables	1	1	0	0	0	0	0
Recyclables separated into at least three containers	0	0	1	1	1	1	1
Mandatory participation	1	0	1	1	1	0	NA*
Promotional services program	1	1	1	1	0	1	NA*
Unit pricing program	0	1	0	1	1	0	NA*
All waste sent to a MRF	1	1	0	0	0	0	0
All recyclables sent to a transfer facility for recycling	0	0	1	1	1	1	1
All yard waste sent to compost facility	1	1	1	1	1	1	1

Note: 1 = yes. 0 = no.

*See Section 2.4.3.

Mandatory ordinances require households to separate specific recyclables from their garbage. These ordinances are aimed at stimulating participation and reducing the amount of materials going to other disposal alternatives. Mandating participation encourages an extra level of support that can have a significant impact in terms of diverting materials. Just the act of passing the ordinance helps publicize and legitimate the program. Enforcement provisions are necessary to show that the municipality is serious about recycling and intends to sustain the program. Even with an ordinance in place, however, most municipalities make a serious effort to educate and motivate the public prior to taking any type of enforcement action.

Enforcement is often applied in steps. Usually, the first step against a nonrecycler is to leave instructions attached to the trash container explaining how to properly prepare recyclables. If the problem is not corrected, then the garbage is not collected and the resident receives a notice of violation. Refusal to pick up improperly separated trash is generally very effective in motivating compliance with the program. If the problem is not corrected after several warnings, then enforcement action can be applied. Most municipalities avoid penalizing citizens for not recycling. In fact, even those communities that actively monitor compliance seldom resort to summons and fines (*Biocycle Journal of Waste Recycling*, 1990).

2.4.1.4 Promotional Services

Public participation is critical to recycling. Although the models do not specify particular educational services, in reality, programs must be thorough and broad to generate the level of response assumed in the participation rates. A quality educational effort should include staff, supplies, and office space for an array of mailings, as well as videotapes, stickers, calendars, media coverage, public presentations, and personal contacts. Many cities have targeted their education efforts at grade school and high school students. Advertising efforts may include placing articles in the newspapers, circulating information at street fairs and festivals, placing signs on city buses, and sponsoring media events such as Seattle's "Cash for Trash" program that rewards residents who do not place recyclables in their trash.

2.4.1.5 Unit Pricing

At least 17 communities employ some type of quantity-sensitive pricing of solid waste management services (see Table 2-7). All of the unit pricing programs shown in

TABLE 2-7. UNIT PRICING PROGRAMS

Community (population)	Date unit pricing program began	Mandatory or optional	If optional, percent participation	(Yes/No) Availability				Municipal or Non-Municipal			
				All Areas	Single Family	Multi-Unit	Commercial	Collection[a]	Disposal[b]	Mgmt	Fees and Containers
Carlisle, PA (19,000)	> 5 years ago	O	not available	Y	Y	Y	N	N/M	N	M	M
Duluthe, GA (10,000)	Early 70's	M		Y	Y	N	N	N/M	N	M,N	M,N
Grand Rapids, MI (170,000)	1973	O	not available	Y	Y	Y	N	M	M	M	M
High Bridge, NJ (4,000)	1988	M		Y	Y	Y if <5 units	N	M	N	M	M
Holland, MI (30,000)	1981	O	10-15%	Y	Y	N	N	N	N	N	N
Ilion, NY (9,500)	June 1, 1988	M		Y	Y	Y	Y-optional	M	N	M	M
Jefferson City, MO (36,000)	> 22 years ago	O	> 90%	Y	Y	N	N	N/M	N	N	N
Lansing, MI (125,000)	1975	O	60-70% (by resident bldgs.)	Y	Y	Y if <5 units	N	M	N	M	M
LaTrobe, PA (12,000)	~10 years ago	M		Y	Y	N	N	M	N	M	M
Newport, NY (2,000)	Couple years ago	M		Y	Y	N	N	N	N	N	N
Olympia, WA (10,400)	1954 or earlier	M		Y	Y	Y	Y	M	M	M	M
Perkasie, PA (6,500)	January 1988	M		Y	Y	Y	Y	M	N	M	M
Plantation, FL (64,000)	15-16 years ago	M		N	Y	Y	Y	N/M	N	N	N
Seattle, WA (500,000)	1981 (revised fee structure)	M		Y	Y	Y limited to few units	N	N/M	N	M	M
Wilkes-Barre, PA (50,000)	1988	O		Y	N	Y 4-20 units	N	M	N	M	M
Woodstock, IL (12,000)	1988	M		Y	Y	N if >2 units	N	N/M	N	N	N

CONTINUED

[a]M means city employees collect waste. N/M means city contracts private hauler. N means residents contract private hauler.
[b]N means disposal at a site or facility that is private or owned and operated by another local government entity; e.g., a county landfill.
Source: RTI, 1989, Table 2-1.

TABLE 2-7. UNIT PRICING PROGRAMS (CONTINUED)

Community	Containers	Volume or Weight Limited	Cost (1989)		Collection		Disposal	Data Available
			Minimum	Per Container	Times/week	Curbside or Backdoor	Landfill, Incinerator, or Transfer Station	
Carlisle, PA	Program bags	V		$1.10 / 30 gal. $0.60 / 15 gal.	1	C	L	N
Duluthe, GA	Program bags	V	In taxes	$8.50 / 20 bags	1	C	L	N
Grand Rapids, MI	Program bags, own cans w/ tags	V,W	1.1 mill tax	$0.45 / bag $0.35 / tag	1	C	L	Limited
High Bridge, NJ	Stickers for own bags or cans	V	$35/qtr gets 52 stickers/year	$1.65 each additional sticker	1	C	T,L	Y
Holland, MI	Program bags, program carts	V		$1.30 / bag or $8-10 / mo. / cart	1	C	L	Limited
Ilion, NY	Program bags	V,W		$1.50 / 30 gal $1.20 / 16 gal	1	C	L	Y
Jefferson City, MO	Program bags	V		$1.30 / bag	2	C	T, L	N
Lansing, MI	Program bags	V,W		$7.50 / 10 bags	1	C	L	N
LaTrobe, PA	Program bags	V,W	$51 / 6 mos.	$0.25 / bag	1	C	T,L	Limited
Newport, NY	Program bags	V,W		$1.50 / 32 gal $1.10 / 28 gal $0.80 / 20 gal	1	C	L	N
Olympia, WA	Own cans; bags cost extra	V,W	Yes	Variety of services	1	C	L	Limited
Perkasie, PA	Program bags	V,W		$0.80 / 20 lb. $1.50 / 40 lb.	1	C	T, L	Y
Plantation, FL	Program bags	V,W		$16 / 20 bags	2	C	L	N
Seattle, WA	Wheeled toters	V,W	At least $10.70 for mini-can	$13.75 / 30 gal can $9.00 / ea. add'l can	1	C, B	T, L	Y
Wilkes-Barre, PA	Program bags	V		$9.30/8, 30-gal bags $5.55/8, 16-gal bags	1	C	T, L	N
Woodstock, IL	Program bags	V,W		$1.22 / bag	1	C	L	Y

Table 2-7 have one feature in common: pricing based on volume. Residents are required to use waste containers (usually bags) that meet certain volume specifications. Even so, service providers generally estimate weights per unit volume when setting prices, and some programs have weight limits. However, enforcing weight limits is costly and seldom done. Fee structures for unit pricing programs vary widely—some programs use per-unit fees, while others use per-unit fees that supplement flat fees (that are either billed directly or included in taxes). Finally, collection characteristics (i.e., frequency, time, and placement of containers) and requirements for special services, such as bulky waste pick-up, vary widely (Research Triangle Institute, 1989).

2.4.1.6 Post-Collection Processing

Post-collection processing refers to what happens to the recyclables after they are collected from households. Some degree of post-collection processing is always beneficial to the sellers of the recovered materials even if it is no more than densifying plastic containers, crushing glass and cans, or bailing paper.[3] Both two-stream separation programs discussed below in Section 2.4.2 send materials to a MRF; all recyclables collected from the multiple-stream separation programs discussed in Section 2.4.3 are sent to a recycling transfer station to be stored until they are shipped to market. All yard waste collected by two-stream and multiple-stream model programs is sent to a centralized facility to be processed into mulch or compost.

2.4.1.7 Participation Rates

Participation rates state the percentage of households expected to participate in a given model program by sorting recyclables from their garbage and setting them out by the curb for pick-up. Participation rate is a function of population, population density, and three program characteristics (i.e., the quality of promotional services, imposition of unit pricing, and adoption of mandatory compliance ordinances).

Deriving reliable, precise relationships between participation rates and their determinants is currently infeasible because of a lack of information on recycling programs. Nonetheless, the following hypotheses are reasonable:

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[3] These activities are typical of recycling transfer stations.

Hypothesis #1—As population increases the participation rate decreases. This inverse relationship is a result of the increased difficulty in enforcing mandatory programs in large population centers as compared to small towns.

Hypothesis #2—As population density increases participation decreases. Increasing the population density generally correlates with increasing the proportion of multi-family units in a given area. Increasing the proportion of multi-family units lowers participation rates because (1) recycling is less convenient for multi-family residents, and (2) enforcing mandatory recycling ordinances is more difficult in multi-family units. Multi-family residents find recycling inconvenient because they have less space in which to store recyclables. Monitoring the compliance of individual multi-family residents is difficult because the residents deliver their recyclables to a central collection site.

Hypothesis #3—Three program characteristics directly increase participation rates:

- using promotional services (i.e., advertising and education programs),
- imposing unit pricing, and
- adopting mandatory compliance ordinances.

Table 2-8 shows the influence of these characteristics on each model program's participation rate. The program options highlighted by boxes in Table 2-8 are the ones used in this analysis.

An effective promotional service campaign includes both how-to information as well as a message that makes people aware that their "individual effort, however small in itself, is part of a mighty earth-community effort" (*Biocycle Journal of Waste Recycling*, 1990, page 46).

Imposing a unit pricing program also has a positive effect on participation rates. As reported in *Biocycle*,

> ...it's hard to beat the overall educational value of the pay-per-bag program. What goes on in the mind of consumers when they must repeatedly go into a store and buy the actual bags they use for their garbage and pay a price that actually reflects the cost of the services is very important. It sends a powerful message on a regular basis that waste disposal is an expensive service, and that if I reduce the amount I throw away by recycling, I will also reduce my garbage bill. It's a different kind of education than reading a flyer or going to a meeting and really seems to bring about an awareness in people of what's really going on. (*Biocycle Journal of Waste Recycling*, 1990, page 73)

TABLE 2-8. MODEL PROGRAMS: PARTICIPATION RATES (%)

Program Option	Characteristic	Influence on Participation Rate	Commodity	Community[a] A (VS/L)	B (VS/M)	C (S/L)	D (S/M)	E (M/M)	F (H/M)	G (H/H)
Multiple-stream option 2	Good promotional services	>	containers	90	90	90	90	80	80	70
	Unit pricing in effect	>								
	Mandatory household compliance	>								
Two-stream option 2	Good promotional services	>	containers	70	70	70	70	65	65	60
	Unit pricing in effect	>	newspaper	85	85	85	85	80	80	75
	Voluntary household compliance	<	yardwaste	80	80	80	80	80	80	80
Multiple-stream option 3	Poor promotional services	<	containers	70	70	70	70	60	60	50
	Unit pricing in effect	>								
	Mandatory household compliance	>								
Two-stream option 1 / Multiple-stream option 1	Good promotional services	>	containers	60	60	60	60	50	50	40
	No unit pricing in effect	<	newspaper	75	75	75	75	65	65	55
	Mandatory household compliance	>	yardwaste	80	80	80	80	80	80	80
Multiple-stream option 4	Good promotional services	>	containers	40	40	40	40	40	40	30
	No unit pricing in effect	<								
	Voluntary household compliance	<								
MS	Composite		containers	60	60	60	60	50	50	40
			newspaper	75	75	75	75	65	65	55
			yardwaste	80	80	80	80	80	80	80

[a] Communities classified as follows:

Population:

VS (very small)	Population ≤ 20,000
S (small)	20,001 ≤ P 100,000
M (medium)	100,001 ≤ P 200,000
H (high)	200,000 ≤ P

Density (persons/square mile):

L (low)	D ≤ 400
M (medium)	401 ≤D ≤ 800
H (high)	801 ≤ D

Not surprisingly, an analysis of the case studies in Section 2.3 leads to the conclusion that programs with mandatory participation ordinances have significantly higher household participation rates than those with voluntary programs. In fact, participation rates above 60 percent are very rare in voluntary programs (Allan, Platt, and Morris, 1989).

Hypothesis #4—Participation rates in multiple-stream programs will not be greater than those in two-stream programs given the following conditions:

Hold constant all variables discussed in hypotheses 1, 2, and 3 (i.e., population, population density, quality of promotional services, imposition of unit pricing, and implementation of mandatory compliance ordinances) and only change the set-out method.

2.4.1.8 Capture Rates

Capture rate (or percent recovery) is the percentage of each target material that a participating household removes from the waste stream. All capture rates shown in Table 2-6 are based on figures recommended to us by OSW. These projections are based, as much as possible, on experiences with operating systems in this country. The rates are applied to both MWCs with RDF and without RDF.

2.4.2 Two-Stream Household Separation Model Programs

Two-stream household separation generally refers to a commingled (mixed) set out of target recyclables in one container with paper stacked and/or bundled and placed near the container. This analysis models two options of the two-stream household separation program to estimate national implementation costs and participation rates (see Table 2-6). Program characteristics common to both options are as follows:

- Target materials are steel cans, aluminum cans, old newspapers, yard waste, glass containers, and PET and HDPE plastic containers.
- Target materials are sorted from garbage by the household, placed at the curb, and collected without further separation.
- Good promotional services are provided to educate and inspire public support for recycling.
- All collected recyclables are sent to a MRF for processing.
- All collected yard waste is sent to a compost facility in the community.

- The capture rate is 60 percent for steel and aluminum cans, 80 percent for old newspapers and yard waste, and 65 percent for glass containers and PET and HDPE plastic containers.

Two-stream household collection options 1 and 2 differ in the following three characteristics:

- Mandatory participation is imposed on households in option 1; participation is voluntary in option 2.
- Unit pricing is in effect in option 2 but not in option 1.
- Because mandatory participation and unit pricing both tend to increase participation, one might expect the participation rate for option 2 to be the same as option 1. However, because it is felt that unit pricing has a greater positive influence on participation than imposing a mandatory ordinance, the participation rate for option 2 is higher than option 1 (see Table 2-8).

2.4.3 Multiple-Stream Separation Model Program

The multiple-stream separation model program requires residents to separate glass by color, to separate other containers by material, to stack and bundle old newspapers, and to bag yard waste. The approach taken to modeling multiple-stream programs begins by describing different programs with the intent of determining a plausible range in their variations. Knowledge of program diversity permits an informed selection of the best average program for use in subsequent analysis.

Four different multiple-stream separation model programs illustrate the variety of options available to local program planners (see Table 2-6). Characteristics common to all four multiple-stream model program options are as follows:

- Steel cans, aluminum cans, old newspapers, yard waste, glass containers, and PET and HDPE plastic containers are the target materials.
- Target materials are separated from garbage by the household, placed at the curb, and collected without further separation.
- All collected recyclables are sent to a recycling transfer facility.
- All collected yard waste is sent to a compost facility in the community.
- The capture rate is 60 percent for steel and aluminum cans, 80 percent for old newspapers and yard waste, and 65 percent for glass containers and PET and HDPE plastic containers.

The four multiple-stream separation model program options differ in the following characteristics:

- Mandatory participation is required by households in options 1, 2, and 3 but not in option 4.
- Unit pricing is in effect in options 2 and 3 but not in options 1 and 4.
- Good promotional services are provided in options 1, 2, and 4 but not in option 3.
- Participation rates vary from 90 percent (option 3) to 30 percent (option 4). (Section 2.4.1.7 explains what causes participation rates to vary.)

The cost of implementing the multiple-stream separation model program was derived by using a hybrid of all four model programs. The hybrid is labelled "program option MS" in Tables 2-6 and 2-8. Its participation rates are intermediate in comparison to those of the other multiple-stream programs. Consequently, program MS has the same participation rates as the least effective two-stream program (two-stream option 1). The estimate of the cost of a multiple-stream program is thus premised on the hypothesis that the effectiveness of the typical multiple-stream program is near the lower end of the range for two-stream programs.

CHAPTER 3
COSTS AND COST-SAVINGS OF MODEL MATERIALS SEPARATION PROGRAMS

The materials separation programs that communities will operate to comply with the materials separation requirement require collection systems and facilities for post-collection processing. A comprehensive accounting of the net cost of a program requires not only a valuation of the resources allocated to the collection system and facilities, but also a valuation of the other resources whose allocation will change. The accounting should therefore include revenues from the sale of recovered materials and cost-savings from the reduction in the consumption of services provided by future municipal waste combustors, municipal solid waste landfills, and ordinary residential garbage collection.

This chapter describes the methodology of estimating the costs and cost-savings of the model materials separation programs. To reflect uncertainties in the estimation of national cost, the methodology produces a range of estimates. The estimate of the cost of the materials separation programs that will operate in response to the materials separation requirement is most appropriately presented as a range because of numerous uncertainties in predicting the choices of the owners of MWCs and the behavior of the residents in their service areas. To produce a range of costs, varying the level of resources applied to administration and the characteristics of composting programs is convenient as well as plausible. The administration of a program may require the substantial addition of resources to demonstrate compliance with the NSPS and EG. Some communities may operate a materials separation program that does not include a composting component; other communities may opt for backyard composting. Additional sensitivity analysis is conducted by varying the methodologies used to estimate avoided landfill costs and avoided residential MSW collection costs.

Section 3.1 addresses a behavioral issue that underlies the calculation of costs and cost-savings for existing MWCs. This issue is whether an owner will avert a reduction in throughput by expanding the catchment area. Section 3.4 through 3.7 detail costs and cost-savings of model materials separation programs with respect to household costs, downsizing MWCs, effect on landfill space, changes in waste composition, and residential collection costs. Section 3.8 briefly defines the method for extrapolating the costs from model communities to communities of different sizes.

3.1 A CRITICAL BEHAVIORAL ASSUMPTION: EXPANSION OF THE CATCHMENT AREA OF EXISTING MWCS

In the absence of mitigating behavior, the amount of waste combusted declines by the amount of separated material. Setting aside the change in heat content that occurs because of materials separation (see Section 3.6), a reduction in throughput reduces tipping fee revenues at all MWCs and electric and steam generation in waste-to-energy units; operating and maintenance costs may also change.

The *Wall Street Journal* recently described the problem facing the owners of the MWC in Portland, Maine, caused by an unexpected decline in throughput:

> The plant started up two years ago, but a hitch soon appeared: When Maine's tourists go south for the winter, the amount of trash declines more than planners had figured. So far, that hasn't hurt the plant, which is obligated to generate a certain amount of power under its financing terms. But Maine towns are expanding recycling programs under a new state law, and that could starve the incinerator for fuel.
>
> So, when Portland and other towns in the Regional Waste Systems cooperative recently were granted state money to increase recycling, they decided not to use it, at least for the time being. "We're not anti-recycling," says Charles Foshay, Regional Waste's director. "But we put the expansion [of recycling] on hold until we have a better understanding of its impact."
>
> Regional Waste, he adds, probably will ask other Maine towns to send trash when its garbage runs low. "But," he adds, "I don't want [garbage] barges from New York." (4/19/90, p. B1)

Recycling and materials separation programs directly affect the financial viability of an MWC. The potential effect is substantial. Alfred Medioli, Vice President and Manager, Moody's Investors Service, observed earlier this year that recycling programs are "already quite significant in any current analysis of projects" and are among the eight issues that "will strongly shape solid waste disposal projects, their financing, their feasibility, and their credit worthiness in coming years" (1990, p. 7). To illustrate, he recounted the difficulties experienced by the owners of a mass-burn unit in Warren County, New Jersey:

> This plant was designed and built before the state's mandated recycling program. It started operating in the summer of 1988, and for the first six months it received 27 percent less garbage than projected, resulting in some degree of operating loss. The Warren plant will likely take waste from neighboring counties. (Ibid., pp. 11-12)

Whether owners of other existing MWCs will also ask nearby towns for their MSW when throughput declines depends on how the cost of obtaining that waste compares with the cost of combusting less waste. This comparison depends on transportation costs, operating costs, tipping fees, and energy prices, all of which vary across communities. Recognizing that the results of this comparison are likely to differ, it was hypothesized that an owner typically will increase the population served (expand the catchment area) to maintain the baseline rate of capacity utilization.

To calculate the new quantity of MSW that a combustor must receive to avert a decrease in throughput, the following three values are essential:

- R_o, original quantity of MSW received[1]
- b, baseline separation rate (with respect to R_o)
- d, gross incremental separation rate (with respect to R_o)[2]

When a new program starts, the resulting reduction in throughput equals R_o*d. To keep the quantity combusted at the original level, the quantity received must increase by R_o*d plus an additional amount (to be specified) to offset baseline separation in the expansion of the catchment area and incremental separation. Although the quantity received has increased by R_o*d, the quantity combusted has increased by less. This shortfall equals R_o*d*b (due to baseline separation[3]) plus R_o*d*d (due to incremental separation[4]); the total shortfall is R_o*d*(b+d). Therefore, to maintain baseline combustion, the quantity received must again increase (by R_o*d*(b+d)) to replace the shortfall. Whenever additional MSW is received, a fraction is combusted—never the whole amount because some is separated due to baseline activity and the rest is separated due to the new materials separation program.

The following equation identifies the requisite new amount of MSW received (R_n):

$$R_n = R_o + R_o*d + R_o*d*(b+d) + R_o*d*(b+d)^2 + R_o*d*(b+d)^3 + \ldots \qquad (3\text{-}1)$$

[1] To be consistent with the proposed rule, the MSW "received" at a combustor includes materials separated in the baseline.

[2] The measurement of diversion is gross of the cap on the credit for compostable materials, and it is gross of the residuals generated in the processing and composting facilities.

[3] The baseline separation rate is assumed the same in all areas.

[4] The incremental diversion rate is assumed the same in all areas.

After collecting terms, this formula becomes

$$R_n = R_o + \sum_{i=0}^{\infty} R_o * d * (b+d)^i \quad (3\text{-}2)$$

The infinite sum is a geometric series with initial term R_o*d and ratio (b+d). The next four equations show progressive simplifications of equation (3-2).

$$R_n = R_o + R_o * d/(1-(b+d)) \quad (3\text{-}3)$$

$$R_n = R_o * [1 + d/(1-(b+d))] \quad (3\text{-}4)$$

$$R_n = R_o * [(1-b-d+d)/(1-(b+d))] \quad (3\text{-}5)$$

$$R_n = R_o * (1-b)/(1-(b+d)) \quad (3\text{-}6)$$

Equation (3-6) states that the new quantity received equals the old quantity received multiplied by the ratio of the baseline combusted fraction (1-b) to the post-separation combusted fraction (1-(b+d)). For example, if the baseline combusted fraction were 10 percent and the post-separation combusted fraction were 5 percent, then the quantity received would double.

It was assumed that the original catchment area and its environs have identical characteristics vis-à-vis municipal solid waste. In the example, the population served would therefore double.

In general, for an existing MWC, the catchment area and the population served increase by a factor equal to (1-b)/(1-(b+d)). The expansion factors for the model programs analyzed range from 1.19 to 1.24.

3.2 COLLECTION SYSTEMS AND PROCESSING FACILITIES

A materials separation program requires equipment, facilities, crews for collection and post-collection processing and administration. The cost of infrastructure and crew for three different model programs in model communities that differ by size of population served and population density were estimated.[5] A three-step method for estimating costs was followed:

1. Characterize the basic elements of collection systems and processing facilities for each model program/model community combination.

2. Determine the appropriate scale of collection and processing.

3. Calculate the annualized capital, operating, and maintenance costs implied by (1) and (2).

The method employed to calculate costs disaggregates the entire collection and processing system into two subsystems (collection and post-collection processing). Further, it disaggregates the subsystems themselves into basic units of equipment, facility, and crew for which individual costs were estimated.

The collection system comprises one subsystem for the collection of newspapers and containers from single-family residences, a second subsystem for gathering these materials from multi-family residences, and a third subsystem for compostable materials. A collection subsystem comprises containers, trucks, and crew. This cost analysis also includes factors that determine the efficiency of collection in each subsystem. The critical factor for collection is the number of households served per hour, which varies with density.[6]

The system for post-collection processing includes one subsystem for newspapers and containers and another for leaves and yard waste. All model programs include one or more composting facilities. A two-stream program includes a composting facility and a materials recovery facility, and a multiple-stream program includes a composting facility and a recycling transfer facility.[7] The classes of equipment vary from facility to facility, but in the entire system the equipment performs the functions of materials handling, sorting, windrow turning, and compacting.

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[5] Chapter 4 focuses on the role of communities; nevertheless, costs, the subject of this chapter, vary by community. Communities are classified as follows:

Population		Density (persons/square mile)	
VS (very small)	$P \leq 20{,}000$	L (low)	$D \leq 400$
S (small)	$20{,}001 \leq P \leq 100{,}000$	M (medium)	$401 \leq D \leq 800$
M (medium)	$100{,}001 \leq P \leq 200{,}000$	H (high)	$801 \leq D$
H (high)	$200{,}001 \leq P$		

[6] Within any model community, collection efficiency varies across subregions (urban, suburban, rural). Efficiency also varies in an overall sense with population density.

Tables 3-1A, B, C and 3-2A, B, C identify the characteristics of the collection systems and processing facilities for model two-stream and multiple-stream programs for three model communities (C, E, and G). The tables list containers, trucks, crews, sites, and facilities and their unit costs. Other relevant details are included.

The scale of collection and processing depends on the separated materials, which differ by program and community. The number of containers (for example, "blue boxes"), size of the truck fleet, and number of collection workers and processing facility operators were determined using the Tellus Institute's computer program (WastePlan) for solid waste management. The inputs to WastePlan are characteristics of the separation program and community and the elements of the collection and processing facility subsystems. WastePlan calculates the quantities of the needed resources and, using input prices, calculates costs.

Table 3-3 reports the average (per Mg) annualized costs for all collection and processing activities by model program and model community.[8] Costs for materials recovery facilities and recycling transfer facilities show economies of scale (see Figure 3-1). Costs for collection systems and compost facilities show constant returns to scale. Average costs become progressively higher as population served decreases.

Uncertainties in the estimation of the national cost of materials separation programs are incorporated by 1) varying the magnitude of the administrative effort that will be required to demonstrate compliance with the materials separation requirement and 2) modifying the hypothesis concerning composting programs. In the lower estimate of costs, additional administrative effort is unnecessary; in the higher estimate, additional effort is necessary, and the rate of expenditure is $35,000 (salary and fringe benefits for one administrator) per year per 25,000 persons served.[9]

Up to this point, the hypothesis concerning composting programs has been that every affected community will operate the same type of program (bagged setout of yard waste and leaves, and central composting). A more plausible prediction is that different types of composting programs will operate. Specifically, costs are developed on the

---

[7] A materials recovery facility houses more types of sorting equipment than a recycling transfer facility. In the latter, the basic activity is moving presorted material from smaller containers (bins in collection trucks) to larger containers (semi-trailers or roll-off bins).
[8] Two combinations are irrelevant—see Chapter 4.
[9] The total expenditure increases in steps: $0—$35,000—$70,000—etc.

TABLE 3-1A. COLLECTION SYSTEMS FOR THE TWO-STREAM MODEL PROGRAM "OPTION 2"

COLLECTION SYSTEMS	Community[a]		
	C (S/L)	E (M/M)	G (H/H)
Single-Family Commingled			
• Truck[b]			
– Purchase Price (1,000 $)	25.0	40.0	62.0
– Service Life (years)	10.0	5.0	7.0
– Other O&M ($/year)	2,496	2,676	4,123
– Collection Crew (number @ $/year)	1.0 @ $28,080	1.0 @ $28,080	1.0 @ $33,696
– Households/hour: Urban, Suburban, Rural	160, 130, 80	160, 130, 80	160, 130, —
• Container Type	Blue Box	Blue Box	Blue Box
– Cost ($/container)	5.00	5.00	5.00
Multi-Family Commingled			
• Truck[b]			
– Purchase Price (1,000 $)	25.0	55.0	55.0
– Service Life (years)	10.0	7.0	7.0
– Other O&M ($/year)	4,064	6,889	6,852
– Collection Crew (number @ $/year)	2.0 @ $28,080	2.0 @ $28,080	2.0 @ $33,696
– Households/hour: Urban, Suburban, Rural	550, 363, 75	550, 363, 75	550, 363, —
• Container Type #1	Blue Box	Blue Box	Blue Box
– Cost ($/container)	5.00	5.00	5.00
• Container Type #2	90 gallon cart	90 gallon cart	90 gallon cart
– Cost ($/container)	24.00	24.00	24.00
Residential Composting			
• Truck[b]			
– Purchase Price (1,000 $)	100.0	120.0	120.0
– Service Life (years)	7.0	7.0	7.0
– Other O&M ($/year)	4,060	3,631	4,042
– Collection Crew (number @ $/year)	2.0 @ $28,080	2.0 @ $28,080	2.0 @ $33,696
– Households/hour: Urban, Suburban, Rural	120, 90, 60	120, 90, 60	120, 90, 60

[a] Communities classified as follows:

Population:

VS (very small)	$P \leq 20,000$
S (small)	$20,001 \leq P \leq 100,000$
M (medium)	$100,001 \leq P \leq 200,000$
H (high)	$200,001 \leq P$

Density (persons/square mile):

L (low)	$D \leq 400$
M (medium)	$401 \leq D \leq 800$
H (high)	$801 \leq D$

[b] Costs are reported per truck.

TABLE 3-1B. PROCESSING FACILITIES FOR THE TWO-STREAM MODEL PROGRAM "OPTION 2"

PROCESSING FACILITIES	Community[a]		
	C (S/L)	E (M/M)	G (H/H)
Materials Recovery Facility (Recycling)			
Capital Costs			
• Land (1,000 $/acre)	7.5	7.5	10.0
• Site Prep (1,000 $/acre)	80.0	80.0	80.0
• Process Building size (sq. ft.)	14,000	17,500	21,500
• Process Building cost ($/sq. ft.)	70	70	70
• Process Building lifetime (years)	20	20	20
• Capacity per site (TPD)	15	35	90
• Equipment Life (years)	7	7	7
• Equipment Costs (1,000 $)			
– Handling	81.4	92.4	200.9
– Separation	202.0	257.0	446.6
– Processing	94.7	123.6	608.3
O&M Costs			
• Employment (Workers/Facility)	5.0	10.0	15.0
• Average Annual Salary (with Fringes)	27,000	27,000	32,400
• Maintenance (% of equipment costs)	3.00	3.00	3.00
• Utilities ($/ton of annual throughput)	1.50	1.50	1.50
• Insurance (% of total capital cost)	0.50	0.50	0.50
• Other O&M (% of total O&M cost)	10.00	10.00	10.00
Composting Facility			
• Land Capacity (Delivered CYs/Acre)	4,500	4,500	4,500
• Cost of Land ($/acre)	7,500	7,500	10,000
• Site Prep ($/acre)	5,000	5,000	5,000
• Pad Construction ($/acre)	5,000	5,000	5,000
• Maximum Acres per Site	10	10	10
• Equipment Cost per Site	75,000	150,000	150,000
• Lifetime of Site (Years)	10	10	10
• Workers per Site	2.0	2.0	2.0
• Average Annual Salary (with Fringes)	15,000	15,000	18,000

TABLE 3-1C. PROGRAM ADMINISTRATION FOR THE TWO-STREAM MODEL PROGRAM "OPTION 2"

PROGRAM ADMINISTRATION COST ($/household)	Community[a]		
	C (S/L)	E (M/M)	G (H/H)
Single-Family Commingled	0.80	0.80	0.80
Multi-Family Commingled	0.80	0.80	0.80
Residential Composting	0.50	0.50	0.50
Additional Record Keeping	3.57	3.46	3.68

TABLE 3-2A. COLLECTION SYSTEMS FOR THE MULTIPLE STREAM MODEL PROGRAM "MS"

COLLECTION SYSTEMS	Community[a]		
	C (S/L)	E (M/M)	G (H/H)
Single-Family Commingled			
• Truck[b]			
– Purchase Price (1,000 $)	25.0	62.0	62.0
– Service Life (years)	10.0	7.0	7.0
– Other O&M ($/year)	2,342	3,683	3,334
– Collection Crew (number @ $/year)	2 @ $28,080	2 @ $28,080	2 @ $28,080
– Households/hour: Urban, Suburban, Rural	130, 100, 60	130, 100, 60	130, 100, 60
• Container Type	3-stacked containers	3-stacked containers	3-stacked containers
– Cost ($/container)	12.00	12.00	12.00
Multi-Family			
• Truck[b]			
– Purchase Price (1,000 $)	55.0	55.0	55.0
– Service Life (years)	7.0	7.0	7.0
– Other O&M ($/year)	9,387	6,207	4,812
– Collection Crew (number @ $/year)	2 @ $28,080	2 @ $28,080	2 @ $28,080
– Households/hour: Urban, Suburban, Rural	400, 264, 60	400, 264, 60	400, 264, 60
• Container Type #1	3-stacked containers	3-stacked containers	3-stacked containers
– Cost ($/container)	12.00	12.00	12.00
• Container Type #2	90 gallon cart	90 gallon cart	90 gallon cart
– Cost ($/container)	24.00	24.00	24.00
Residential Composting			
• Truck[b]			
– Purchase Price (1,000 $)	100.0	120.0	120.0
– Service Life (years)	7.0	7.0	7.0
– Other O&M ($/year)	4,060	3,631	3,364
– Collection Crew (number @ $/year)	2 @ $28,080	2 @ $28,080	2 @ $28,080
– Households/hour: Urban, Suburban, Rural	120, 90, 60	120, 90, 60	120, 90, 60

[a] Communities classified as follows:

Population:		***Density (persons/square mile):***	
VS (very small)	$P \le 20,000$	L (low)	$D \le 400$
S (small)	$20,001 \le P \le 100,000$	M (medium)	$401 \le D \le 800$
M (medium)	$100,001 \le P \le 200,000$	H (high)	$801 \le D$
H (high)	$200,001 \le P$		

[b] Costs are reported per truck.

TABLE 3-2B. PROCESSING FACILITIES FOR THE MULTIPLE STREAM MODEL PROGRAM "MS"

PROCESSING FACILITIES	Community		
	C (S/L)	E (M/M)	G (H/H)
Materials Recovery Facility (Recycling)			
Capital Costs			
• Land (1,000 $/acre)	7.5	7.5	7.5
• Site Prep (1,000 $/acre)	30.0	30.0	30.0
• Process Building size (sq. ft.)	13,000	16,000	21,000
• Process Building cost ($/sq. ft.)	50	50	50
• Process Building lifetime (years)	20	20	20
• Capacity per site (TPD)	10	27	75
• Equipment Life (years)	10	10	10
• Equipment Costs (1,000 $)			
– Handling	81.4	92.4	157.0
– Processing	94.7	123.6	154.0
– Conveyor Belt	45.0	50.0	115.0
O&M Costs			
• Employment (Workers/Facility)	4.0	8.0	12.0
• Average Annual Salary (with Fringes)	27,000	27,000	27,000
• Maintenance (% of equipment costs)	3.50	3.50	3.50
• Utilities ($/ton of annual throughput)	1.50	1.50	1.50
• Insurance (% of total capital cost)	5.00	5.00	5.00
• Other O&M (% of total O&M cost)	10.00	10.00	10.00
Composting Facility			
• Land Capacity (Delivered CYs/Acre)	4,500	4,500	4,500
• Cost of Land ($/acre)	7,500	7,500	7,500
• Site Prep ($/acre)	5,000	5,000	5,000
• Pad Construction ($/acre)	5,000	5,000	5,000
• Maximum Acres per Site	10	10	10
• Equipment Cost per Site	75,000	150,000	150,000
• Lifetime of Site (Years)	10	10	10
• Workers per Site	2.0	2.0	2.0
• Average Annual Salary (with Fringes)	15,000	15,000	15,000

TABLE 3-2C. PROGRAM ADMINISTRATION FOR THE MULTIPLE-STREAM MODEL PROGRAM "MS2"

PROGRAM ADMINISTRATION COST ($/household)	Community[a]		
	C (S/L)	E (M/M)	G (H/H)
Single-Family Commingled	0.80	0.80	0.80
Multi-Family Commingled	1.20	1.20	1.20
Residential Composting	0.50	0.50	0.50
Additional Record Keeping	3.57	3.46	3.68

TABLE 3-3. MODEL PROGRAM COLLECTION AND FACILITY COSTS (ANNUALIZED $/MG)

	Community[a]						
	A (VS/L)	B (VS/M)	C (S/L)	D (S/M)	E (M/M)	F (H/M)	G (H/H)
Two-Stream, Option 1							
Single-Family Commingled Collection[b]	N/A	78	80	76	88	89	92
Multi-Family Commingled Collection[b]	N/A	86	104	83	88	87	80
Materials Recovery Facility	N/A	430	160	160	96	53	67
Compost Collection[b]	N/A	40	47	37	37	37	30
Compost Facility	N/A	51	19	18	15	14	17
Additional Record Keeping	N/A	0	12	12	13	14	14
Overall System	N/A	266	152	143	116	100	96
Two-Stream, Option 2							
Single-Family Commingled Collection[b]	82	76	79	75	84	86	89
Multi-Family Commingled Collection[b]	108	85	101	84	86	78	78
Materials Recovery Facility	374	374	141	141	76	46	53
Compost Collection[b]	50	40	47	37	37	37	30
Compost Facility	51	51	18	18	15	14	17
Additional Record Keeping	0	0	12	12	12	12	13
Overall System	262	255	149	141	112	98	97
Multiple-Stream							
Single-Family Commingled Collection[b]	179	165	176	163	178	175	N/A
Multi-Family Commingled Collection[b]	171	126	147	116	117	108	N/A
Recycling Transfer Facility	247	247	128	128	75	40	N/A
Compost Collection[b]	50	40	47	37	37	37	N/A
Compost Facility	51	51	18	18	15	14	N/A
Additional Record Keeping	0	0	12	12	14	14	N/A
Overall System	236	222	175	161	136	121	N/A

[a] Communities classified as follows:

Population:		*Density (persons/square mile):*	
VS (very small)	P ≤ 20,000	L (low)	D ≤ 400
S (small)	20,001 ≤ P ≤ 100,000	M (medium)	401 ≤ D ≤ 800
M (medium)	100,001 ≤ P ≤ 200,000	H (high)	801 ≤ D
H (high)	200,001 ≤ P		

[b] Per Mg collected.

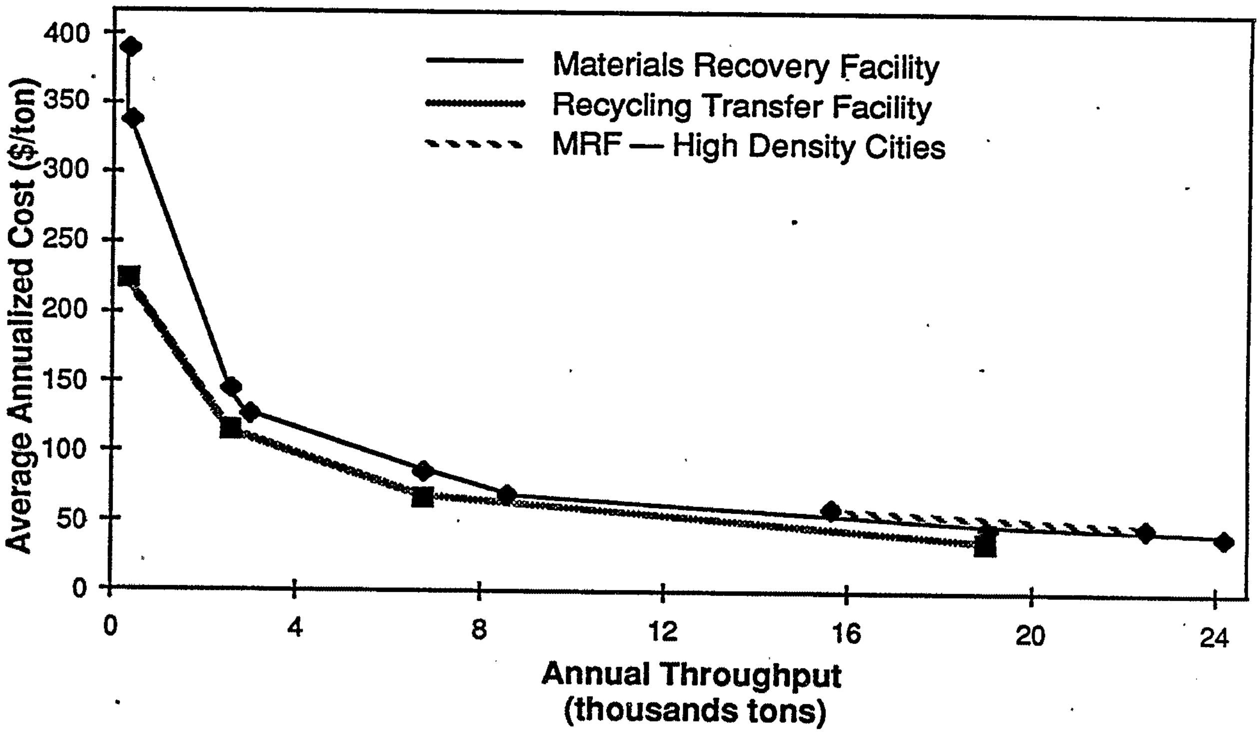


Figure 3-1. Average Annualized Facility Costs

assumption that only 75 percent of the model communities have a program defined by bagged setout and centralized composting; 20 percent have a pre-existing composting program; and 5 percent start a backyard composting program in response to the materials separation requirement.[10] Although predicting the selection of a composting program on the basis of population and density (as was done for recycling programs), would have been ideal, the schedule necessitated a simpler approach to estimating the national cost of composting programs. This estimate was made by calculating the cost of bagged setout and centralized composting for every model community and adjusting the cost and avoided costs following the 75 percent—20 percent—5 percent distribution of program types.[11] Note that Tables 3-1, 3-2, and 3-3 report the unadjusted costs for a bagged setout and centralized composting program.

3.3 HOUSEHOLD COST OF MATERIALS SEPARATION

The flow of separated material begins at someone's home when he or she bundles newspapers, bags leaves, or places used beverage containers in a "blue box" and sets things out for curbside pickup. This effort may seem as though it is free. No exchange occurs; the collection and processing services provided by the householder are not traded in the market. However hidden, resources are consumed: the householder takes storage space for the blue box away from other uses, and he or she could have spent time in another activity.

It is very likely that the materials separation programs that communities operate to comply with the NSPS and EG will require households to process, sort, store, or otherwise control the way in which MSW is provided for collection. Such programs impose some costs on those households that wouldn't voluntarily undertake the practices mandated by the program. Time and money the household spends washing glass, stacking newsprint, clearing and organizing storage space, etc. are real resource costs and are properly considered as a cost of materials separation. One widely accepted measure of this cost is the compensating variation: the minimum amount of money paid to a household which—if the materials separation program is implemented—would leave the household as well off as before the program (Just, Hueth, and Schmitz, 1982).

[10] The effect on costs (other than a householder's opportunity cost) and cost savings is the following: 20 percent of the programs would generate neither costs nor cost savings; the other 5 percent would not generate costs.

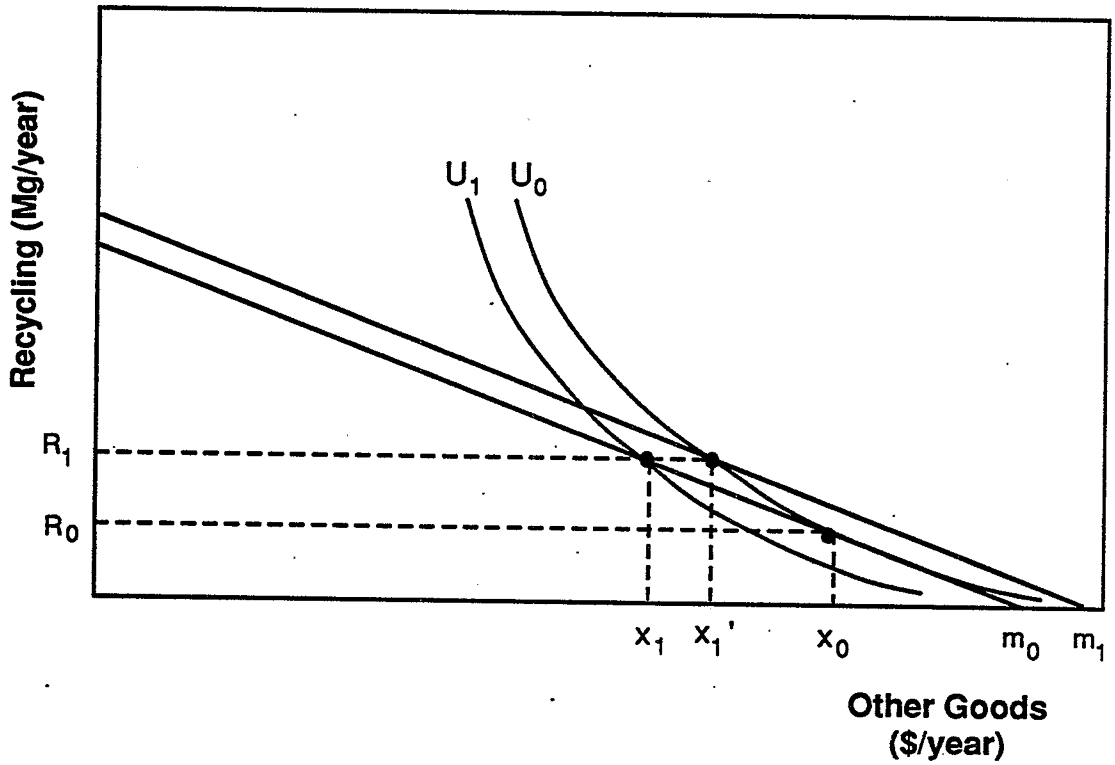
[11] For each model community, the capital, operating and maintenance costs of the composting program are reduced by 25 percent. The cost savings are reduced by 20 percent of the savings attributable (on the basis of weight) to yard waste and leaves.

The compensating variation measure of the household's cost of materials separation is illustrated in Figure 3-2. As depicted in that figure, a utility maximizing household has an initial income of m_0, consumes x_0 units of other goods (denominated in dollars) and voluntarily provides R_0 units of recycled material (denominated in megagrams). The utility level obtained is U_0. With materials recycling, the household is obliged to increase its recycling efforts by way of separating R_1 units of MSW. This effort, with its attendant time and expenditure levels, reduces the maximum attainable level of utility to U_1. The compensating variation is the minimum income supplement that would allow the household to recover its original level of utility and still meet the material separation requirement R_1. This income shift is represented by the new income constraint m_1 and the compensating variation is the difference, along the Other Goods axis, between x_1' and x_0.

Application of compensating variation measures of cost in the case of materials separation differ from more common examples because costs arise from requiring the household to met specified levels of certain activities, rather than from direct price increases in the goods consumed. This difference, however, does not in any way affect the appropriateness or applicability of compensating variation as a measure of the household costs of materials separation.

Morris and Holthausen (1990) have constructed a model of household MSW management the includes both recycling and source reduction as alternatives to conventional mixed waste disposal. They have estimated parameters for a two-good version of the model that can be used to simulate the response of an "average" household to a curbside materials separation program. Parameter estimates used in Morris and Holthausen's model are based on both national and local waste flow data and national income and expenditure data.

With this model, one can solve for household activity levels, including recycling, that would be voluntarily selected by the household as it attempts to maximize utility. Using the model a second time, one can impose the constraint that the household recycles 25 percent (by weight) of the waste it originally generated and solve for new levels of utility-maximizing household activity. The compensating variation that measures the difference in household cost between these two solutions is found by solving the model for the minimum income increase that would allow the household to both achieve the materials separation requirement and the initial, higher level of utility. The income



R_0 - Original recycling without Materials Separation

R_1 - Recycling with Materials Separation

Household Cost ≡ $x_1' - x_1$; income supplement required to attain original level of utility

Figure 3-2. Household Cost of Recycling

supplement required in this scenario is about $10 per year for incremental recycling of .16 Mg more MSW. In other words, the average household cost of meeting the materials separation requirement through curbside recycling is estimated to be about $10 per year ($61/Mg of additional MSW recycled).

This estimate should be regarded as both crude and preliminary in as much as the model is highly aggregate and many of the data used to estimate the model are coarse. Although this estimate is plausible for some households, the true average household cost of the materials separation requirement may be either greater or less. The uncertainty in extrapolating to all householders who will be affected by the regulation is great. Consequently, this category of cost is not included in the national analysis.

3.4 DOWNSIZING CREDIT FOR PLANNED MWCS

As outlined in Section 3.1, estimates of regulatory impacts were developed for existing MWCs under the behavioral assumption that the plant owner will increase the population served in anticipation of the diversion of up to 25 percent of the waste stream. Aside from co-firing with non-waste materials, the owners of existing plants who wish to maintain the baseline rate of capacity utilization have few alternatives available to them because increasing the size of the service area may be difficult or costly for some owners; however, owners of planned MWCs will probably respond by downsizing the MWC in the planning stages rather than risk having to operate at a reduced capacity utilization.

For MWCs subject to New Source Performance Standards (NSPS), estimated impacts are based on the behavioral assumption that solid waste managers will downsize planned capacity in response to the materials separation requirements. The methodology used to calculate the cost savings due to downsizing is outlined below.

First the study developed baseline projections of the number of MWCs, distribution of capacity, estimated total capacity, and distribution of plant technology consistent with the projections developed for the *Economic Impact of Air Pollutant Emission Standards for New Municipal Waste Combustors* (EPA, 1989). Without the effects of downsizing, an estimated 14.25 million Mg per year will be processed in 67 planned MWCs.

Then the total annualized cost was estimated, including baseline and control costs for air emission requirements but excluding the cost of materials separation requirements for each category. These costs were estimated without incorporating downsizing. The cost model and assumptions used to calculate these costs are contained in the *Economic Impact of Air Pollutant Emission Standards for New Municipal Waste Combustors* (EPA, 1989).

Next, calculating the corresponding percent reduction in total annualized costs was accomplished by using the percent reduction in total waste flows for each of the plant categories. For the purposes of this analysis, percent reduction in costs is equivalent to percent reduction in waste flows. Total cost savings are the difference between the total cost without downsizing and total cost with downsizing.

After downsizing an estimated 12.3 million Mg per year will be processed at planned MWCs. This figure represents an overall 17.16 percent reduction in total waste processed. Note that percentage reduction in waste flows for each category of plants may be more or less than the overall average, depending on the characteristics of the model programs associated with the individual plants within each category.

The costs presented in Table 3-4 are used only as a rough estimate of the cost savings associated with downsizing. The estimated total cost savings presented here do not account for economies of scale or differences in technology.

The downsizing credit of approximately $90 million dollars reflects adjustments in the distribution of composting programs (see Section 3.2 above). When every model community starts a bagged composting program, the credit is approximately $103 million dollars. It is a larger credit because every megagram of yard waste and leaves collected is one less megagram of waste combusted at an MWC. When, instead, 20 percent of the model communities have a pre-existing composting program, a planned MWC would have already been appropriately sized and an additional reduction in size would be inappropriate. At the national level, the adjusted downsizing credit is calculated according to the following formula:

$$\left(1 - \frac{.2Y}{Y+O}\right) * \$103 \text{ million} \qquad (3\text{-}7)$$

In the formula, Y is the weight of yard waste and leaves collected and O is the weight of newspapers and containers collected. The fraction Y/(Y+O) is the fraction of the unadjusted downsizing credit attributable to yard waste and leaves. The results reported in Chapter 6 are based on the downsizing credit of $90 million dollars.

TABLE 3-4. DOWNSIZING CREDITS

Model Plant Number	Estimated Percent Waste Flow Reduction	Without Downsizing National Level Annualized Post-Regulatory Cost (10^3)	With Downsizing National Level Annualized Post-Regulatory Cost (10^3)	Percent Reduction in Costs
1	18.01%	$75,149.34	$61,614.95	18.01%
2	16.26%	$75,436.92	$63,170.87	16.26%
3	16.62%	$155,290.03	$129,480.82	16.62%
4	16.68%	$35,900.42	$29,912.23	16.68%
5	16.68%	$44,740.42	$37,277.72	16.68%
6	16.23%	$87,066.03	$72,935.22	16.23%
7	16.31%	$56,035.91	$46,896.45	16.31%
8	17.25%	$11,039.44	$9,135.14	17.25%
9	17.81%	$1,946.85	$1,600.12	17.81%
10	17.98%	$11,468.14	$9,406.17	17.98%
11	15.88%	$20,396.01	$17,157.12	15.88%
12	15.88%	$44,871.81	$37,746.16	15.88%
Total Cost (10^3/yr)		$619,341.31	$516,332.96	16.63%
Total Waste Flow (Unadjusted Composting) (10^6 Mg/yr)		14.95	12.48	16.52%
Total Cost Savings (Unadjusted Composting) (10^3/yr)		—	$103,008.34	
Total Cost Savings (Adjusted Composting) (10^3/yr)			$90,113.02	

Notes:
1) Percent waste flow reduction estimated using Waste Plan model.
2) National level annualized post-regulatory costs are baseline annualized costs plus costs of the air emission requirements under the proposed regulation.
3) For the purposes of this analysis, percent reductions in costs are equal to the percent reduction in waste flows.

3.5 AVOIDED LANDFILL COSTS

It is hypothesized that owners of existing MWCs will avert a reduction in the flow of waste to their plant by obtaining waste from expanded catchment areas. This waste will consequently be diverted from a municipal solid waste landfill (MSWLF). Landfill space is a valuable resource, so the avoided cost of landfilling should enter into a full accounting of the cost of the materials separation requirement.

3.5.1 Greater Estimate of Avoided Landfill Costs

Avoided landfill costs were calculated by using the estimates of the full costs of disposal provided by the Office of Solid Waste (Burke, 1990). The costs in Table 3-5 "reflect total costs after implementation of the draft final rule for revisions to the Subtitle D criteria for MSWLFs" (Ibid., p. 1). Tables 3-6A and 3-6B describe the distribution of landfills by size and type, respectively.[12]

An average cost was calculated using two different methods. In the first, each landfill counts equally. In the second, each ton of daily landfill throughput counts equally.

Assuming that size and type are independent, the average cost calculated by equally weighting landfills is $62.60 per ton. The other average cost is $20.23 per ton.

Several considerations imply that the correct average is an intermediate figure. The first average ($62.60) is too high:

- Landfills nearest an MWC would not be the smallest landfills—this average overestimates the importance of small landfills relative to the average cost of landfilling all waste.
- This average surely overstates the costs, if for no other reason than that the cost of transporting waste from the expanded catchment area to an MWC is probably higher than the cost of transportation to the landfill, which the calculations do not include.

The second average is too low:

- MWCs are found in densely populated areas with higher than average land cost, but the distributions of landfill costs reflect size and type—not population density.

[12] It is assumed that size and type are independently distributed.

TABLE 3-5. BASELINE AND COMPLIANCE COSTS FOR NEW AND EXISTING FACILITIES (TOTAL ANNUALIZED COST PER TON)[a]

MSWLF Size (TPD)	Final Rule				
	Uniform Standard		Performance Standard[b]		
	On-Site Clay	Off-Site Clay	S/S	U/S	U/V
10	$101	$106	$97	$84	$78
25	67	72	64	54	49
75	44	47	42	35	32
175	28	31	26	21	18
375	20	22	18	14	12
750	14	15	13	10	9
1500	14	16	13	10	8

[a]Total costs include baseline. MSWLF sizes listed in tons per day (TPD).
[b]Performance standard modeled for three designs.
U/V = unlined with a vegetative cover
U/S = unlined with a synthetic cover
S/S = synthetic liner with a synthetic cover.

TABLE 3-6A. SIZE DISTRIBUTION

MSWLF Size (TPD)	Fraction of Total Number of Landfills
10	0.513
25	0.170
75	0.131
175	0.073
375	0.055
750	0.031
1500	0.026

TABLE 3-6B. TYPE DISTRIBUTION

Types of Landfill	Fraction of Total Number of Landfills
Uniform On-site Clay	0.202
Standard Off-site Clay	0.071
S/S	0.158
U/S	0.004
U/V	0.565

The dilemma is resolved by using the simple average of \$62.60 and \$20.23 or \$41.42 per ton (\$45.65/Mg). The avoided landfill cost will be calculated by multiplying \$45.65 times each megagram of MSW shipped to an existing MWC from the expanded portion of a catchment area.

3.5.2. Lesser Estimate of Avoided Landfill Costs

Another way of calculating avoided landfill costs uses the elasticity of cost with respect to size. To illustrate, if the elasticity were 0.6, the average cost of landfilling \$50 per ton, and the reduction in waste flow 100 tons, then the total reduction in cost would be \$3000 (0.6*50*100).

Looking at the issue from a long-run perspective, the planned size of a landfill would vary according to the expected rate of use: a landfill that would receive 10 megagrams per day would be replaced with a 7 1/2 megagram per day landfill if the expected flow of waste were to fall by 25 percent. All costs are variable costs, marginal cost equals average cost, and some capital expenditures would be avoided with a reduction in planned capacity. In the short run, the capital expenditures associated with an oversized (after the reduction waste flow) landfill could not be recovered. The long-run perspective produces an upper bound (i.e., the maximum reduction in cost).

The first step in this approach is to calculate the elasticity of cost with respect to size by statistically estimating the relationship between cost and size. Using the figures in Tables 3-5 and 3-6B, the average costs range from \$87.660/ton for a 10 TPD landfill to \$10.578/ton for a 1500 TPD landfill.[13] Using the functional form that assumes a constant point elasticity with respect to size, the following equation results:[14]

$$\text{LN (weighted average cost)} = 5.485 - .450*\text{LN(size)} \qquad (3\text{-}8)$$

After exponentiating both sides and expressing total cost as a function of size, the equation becomes:

$$\text{Total Cost} = 241*(\text{size})^{.55} \qquad (3\text{-}9)$$

Equation (3-9) implies a point elasticity of 0.55 for a change in size (within the long run also equals the change in waste flow when both are expressed as fractions). For

[13] The weighted average costs (total annualized cost per ton) are: 87.660, 56.659, 37.081, 22.219, 15.282, 11.072, and 10.578.

a 25 percent reduction in the quantity (weight) going to a landfill, the long-run reduction in cost is about 59 percent.[15]

The next step is to estimate the average cost of landfills near MWCs. Using the National Survey of Solid Waste (Municipal) Landfill Facilities (U.S., E.P.A., 1988b) made it possible to determine the nearest landfill to 100 MWCs and the average size of these landfills. For a landfill of that size, the average cost was computed using equation (3-8). Significantly, the data used to estimate equation (3-8) reflect conditions across the nation. The average cost implied by these data is unlikely to be representative of the average cost typical of the population of landfills that are near to MWCs. Landfill costs in service areas of MWCs may be expected to be greater than for the entire nation because MWCs generally serve urban areas. Labor and land costs are likely to be higher. Some adjustment in the average cost determined by equation (3-8) is appropriate. Unfortunately, no studies of regional variation in cost exist. The best approximation to cost that is available comes from a survey of tipping fees (Pettit, 1989). The difference between tipping fees in the Northeast and the entire nation is $18.55/ton (Ibid., p. 101). A somewhat arbitrary urban premium of $18.55/ton was added to the average cost determined by equation (3-8) to give an average cost of $33.97/ton or $37.81/Mg for landfills near MWCs.

The lesser estimate of avoided landfill costs is based on an elasticity of 0.59 and an average cost of $37.81/Mg. The unit avoided cost is therefore $22.31/Mg.

3.6 IMPLICATIONS OF A CHANGE IN WASTE COMPOSITION

The proposed rule targets certain components of MSW for removal from the combusted waste stream: paper and paperboard, glass, aluminum, ferrous metals, plastics, and yard waste. Selective removal changes the composition of the waste stream and heat and ash content. The change in heat content may change the value received (per Mg of waste combusted) from the generation of steam and electricity. The change in ash content affects the cost (per Mg of waste combusted) of landfilling the ash.

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[14] The R-squared is 0.986 and the standard error of the coefficient on size is 0.024.

[15] The reduction in cost varies little over a wide range of size reductions. For a 5 percent reduction in size, the reduction in cost is 56 percent; for a 50 percent reduction in size, the reduction in cost is 63 percent.

Table 3-7 describes the baseline composition of residentially generated, combusted MSW and the post-separation composition for several model materials separation programs. The maximum increase in heat content is approximately 9 percent.[16] The maximum increase in ash content is approximately 12 percent.[17]

The value of energy recovery depends on the type of MWC. For mass burn plants (the most common), the revenue from the sale of energy ranges from nothing to $27.40 per megagram of combusted waste (EPA, 1988c, Table 3-4, p. 3-19). For refuse-derived-fuel plants, the revenue ranges from $40.00 to $40.20 per megagram of combusted waste (Ibid.). The value for refuse-derived-fuel plants is most unrepresentative because of the relative rarity of that type and the pre-processing of the waste. The representative range of the value of energy recovery is from nothing to $32.30 per megagram of combusted MSW. For modular plants, the range is from nothing to $32.30 per megagram of combusted waste (Ibid.).

The increase in the value of energy recovery may be as high as $2.96 per megagram combusted (0.0917 * $32.30). An important assumption is that the basis of the capacity of an MWC is throughput of waste.

If the basis of capacity were BTU rather than throughput, the net effect of a change in waste composition would be negative for existing MWCs. An existing MWC would combust less waste, generate the same amount of energy, and receive the same total revenue from the sale of energy. The expansion of the catchment area would be less, reducing the savings from avoided landfill costs (valued at $45.64/Mg). Without additional information on technological constraints, concluding whether the change in heat content from a change in waste composition would lead to a savings or loss is not possible.

In the baseline, one megagram of combusted MSW generates 0.2622 megagrams of ash. The disposal cost ranges from $25.86 /Mg (Radian, 1990) to $45.64/Mg (the average landfilling cost calculated in the previous section above). The ash disposal cost is therefore $6.78 to $11.96 per megagram combusted. Because of the change in waste

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[16] This change occurs in the two-stream model program "option 2" in the small and very small model communities.

[17] This change occurs in the multiple-stream model program and the two-stream program "option 1" in the high-population, high-density model community.

TABLE 3-7. PRE- AND POST-SEPARATION COMPOSITION OF MSW

	Residential Composition of Combusted MSW Pre-Separation (%)	Residential Composition of Combusted MSW Post-Separation by Community and Program (%)		
	Doesn't Vary by Community	SM-2 SL-2 VSM-2 VSL-2	VSL-MS VSM-MS SL-MS SM-MS HH-2 SM-1 SL-1 VSM-1	HH-MS HH-1
Newspaper	8.69	4.02	4.86	6.48
Glass	10.38	7.82	9.29	10.50
Aluminum	1.06	0.89	0.95	1.07
Ferrous	2.65	2.22	2.37	2.68
HDPE & PET Plastic	4.13	3.26	3.52	4.07
Appliances	0.00	0.00	0.00	0.00
Yard Waste	10.81	5.63	5.44	5.18
Leaves	15.15	7.90	7.63	7.26
Stumps	0.00	0.00	0.00	0.00
Books	5.83	8.44	8.15	7.76
Office Paper	0.64	0.92	0.89	0.85
Comm. Printing Paper	1.59	2.30	2.22	2.12
Tissue & Towel	3.18	4.60	4.45	4.23
Nonpackaging Paper	1.27	1.84	1.78	1.69
Pkg. Paper/Paperboard	3.07	4.45	4.30	4.09
Corrugated Cardboard	5.40	7.82	7.56	7.19
Misc. Glass	1.06	1.53	1.48	1.41
Misc. Scrap Alum.	0.64	0.92	0.89	0.85
Misc. Ferr. Scrap	4.13	5.98	5.78	5.50
Nonpkg. Plastic	3.39	4.91	4.74	4.51
Woodwaste	0.64	0.92	0.89	0.85
Foodwaste	6.78	9.82	9.48	9.03
Textiles	1.91	2.76	2.67	2.54
Leather	2.12	3.07	2.96	2.82
Tires	1.38	1.99	1.93	1.83
Ceramics & Misc. Inorganics	3.28	4.75	4.59	4.37
Misc. Organics	0.85	1.23	1.19	1.13
Sum	100.00	100.00	100.00	100.00
Change in:				
Ash content		+4.39%	+8.66%	+12.12%
Energy		+9.17%	+7.96	+7.46%

Source: Radian.

composition, the disposal cost increases from $0.30 to $1.45 per megagram of residentially generated combusted MSW.[18] The increase in cost at the national level was not estimated.

3.7 AVOIDED RESIDENTIAL MSW COLLECTION COSTS

A materials separation requirement for municipal waste combustors will reduce the quantity of refuse that needs to be collected in communities. This reduction may in turn reduce the costs of refuse collection in affected communities. Intuitively, a materials separation program reduces the cost of conventional refuse collection by reducing the quantity of conventional refuse to be collected. In addition, if quantity reductions are significant, some communities that now collect refuse twice weekly may find it acceptable to collect refuse once weekly, allowing cost savings apart from the quantity reduction alone. The purpose of this section is to develop and present an approximation of the range of refuse collection cost savings in affected communities that is attributable to a materials separation requirement.

3.7.1 Greater Estimate of Avoided Costs

The following variables must be known to estimate the refuse collection cost saving in a given community that is attributable to a materials separation requirement:

- the baseline refuse collection cost in the community,
- the relationship between refuse collection costs and determining variables such as refuse quantity and collection frequency, and
- the expected impact of materials separation on these pertinent cost-determining variables.

The greater estimate of avoided costs results from using WastePlan to model the effect of a recycling program on residential garbage collection (Mathias, 1990). For three model communities,[19] the cost of garbage collection was estimated twice: once without a recycling program and again with a recycling program (in particular, the two-stream program "Option 2"). Garbage collection occurs once weekly in both scenarios. The savings in total, annualized garbage collection cost is 16 percent to 17 percent of a

18 Calculated in this way: 0.0439 * $6.78 and 0.1217 * $11.96.

19 The communities are high population/high density, medium population/medium density, and very small population/low density.

baseline collection cost of 27-38 dollars per ton, corresponding to diversion rates of 28-29 percent.

This analysis implies a savings of $23.30 for each megagram of residential waste that is diverted from the ordinary garbage collection system. This figure will be used for each model program and community.

3.7.2 Lesser Estimate of Avoided Costs

For purposes of estimating the lower end of the range of avoided costs, it is assumed that for all communities a baseline (without materials separation) refuse collection cost of $100 per household per year. Savas and Stevens (1978) present annual per-household refuse collection costs for communities of different sizes and collection arrangements. Their estimates are derived statistically from a survey of 315 cities. Statistical estimates (in 1974 dollars per household per year) range from as low as $11 to as high as $65.

Using the services component of the personal consumption expenditures implicit price deflator, these 1974 estimates are equivalent to a range of $30 to $179 per household per year in 1989 dollars. The low end of the range is for once-a-week, curbside collection in a large city with low collector wages, assuming 0.9 Mg (one ton) of refuse per household per year. The high end of the range is for twice-a-week, backyard collection in a small town with high collector wages, assuming 1.8 Mg (two tons) of refuse per household per year. The mid-point of the range is $104.50 per household per year ($ 1989), about the assumed $100 estimate.[20]

Stevens (1978) estimates the cost of refuse collection as a function of the collector's wage, the total quantity of refuse collected per year, market structure (public monopoly, private monopoly, competition), frequency of collection (once or twice weekly), pick-up location (curbside or backyard), quantity of per-household refuse collected per year, number of households per square mile, and variability of weather conditions. To examine the nature of scale economies in refuse collection, Stevens separately estimates log-log equations for four community size groups: population fewer

[20] In the model communities, a household generates slightly more than 1 Mg (less than 1.2 tons) of municipal solid waste each year (generation measured as gross discards). It is therefore assumed that residential refuse collection costs an average of $94.41/Mg ($85.63/ton) per year.

than 20,000, population between 20,000 and 30,000, population between 30,000 and 50,000, and population over 50,000.

Stevens shows the most significant cost determinants to be wages (positive relationship), total quantity of refuse collected (positive relationship), quantity of refuse collected per household holding total quantity constant (negative relationship), frequency of collection (positive relationship), and pick-up location (backyard is more costly than curbside). The estimated regression coefficients can be interpreted as partial elasticities, indicating the percentage change in refuse collection cost given a small percentage change in refuse quantity or frequency of collection.

For purposes of this approximation, it is assumed that materials separation would have *no impact* on the following variables: wages, market structure, and pick-up location. Some or all of the following variables *might be affected* by materials separation: total quantity of refuse collected per year, per-household refuse collected per year, and frequency of collection.

The percent reduction in refuse collection costs is calculated under two scenarios using Stevens' regression coefficient estimates and an assumed baseline household annual collection cost of $100 in all communities. One scenario assumes that the quantity (and quantity per household) of refuse declines with materials separation and that communities leave the frequency of collection unchanged (Table 3-8A). For a 25 percent reduction in collection,[21] the cost of collection falls by 1.43 percent to 3.35 percent, depending on the population served.

A second scenario assumes that the total quantity (and quantity per household) of refuse declines with materials separation *and* that communities respond by reducing the frequency of collection from twice-weekly to once-weekly. If the cost of collection were the only consideration, it is plausible that communities would reduce collection frequency. Table 3-8B shows that the reduction in collection cost would be substantial: about 22 percent when collection occurs weekly instead of semi-weekly. Anecdotal evidence suggests that opposition from inconvenienced residents and displaced workers may inhibit or delay the reduction in collection frequency (*New York Times*, 1990). These conditions presumably vary greatly from city to city, and predicting

[21] The model programs reduce residential collection by approximately 25 percent.

TABLE 3-8A. PERCENT REDUCTION IN REFUSE COLLECTION COST ASSUMING NO CHANGE IN FREQUENCY OF REFUSE COLLECTION

	Population of Community			
Refuse Reduction	**Under 20,000**	**20,000 to 30,000**	**30,000 to 50,000**	**Over 50,000**
One percent	0.13	0.10	0.13	0.06
Ten percent	1.34	1.03	1.33	0.57
Twenty percent	2.68	2.06	2.66	1.14
Twenty-five percent	3.35	2.58	3.33	1.43
Thirty percent	4.02	3.09	3.99	1.71

TABLE 3-8B. PERCENT REDUCTION IN REFUSE COLLECTION COST ASSUMING HALVED FREQUENCY OF REFUSE COLLECTION

	Population of Community			
Refuse Reduction	**Under 20,000**	**20,000 to 30,000**	**30,000 to 50,000**	**Over 50,000**
One percent	18.30	19.10	19.73	19.79
Ten percent	19.51	20.03	20.93	20.30
Twenty percent	20.85	21.06	22.26	20.87
Twenty-five percent	21.52	21.57	22.92	21.16
Thirty percent	22.19	22.09	23.59	21.44

reductions in collection frequency would be very speculative. Therefore, the estimation of the reduction in regular garbage collection cost is restricted to the case in which frequency is unchanged.

Because the baseline refuse collection cost is per household, the number of households in all communities in each of the four community size categories can be estimated. These estimates are derived by dividing the population of each affected community[22] in the MWC data base by 2.7, an estimate of the average number of persons per household.

The estimate of the net cost of the materials separation requirement (see Chapter 6) includes the avoided cost of residential refuse collection calculated under the assumption that collection frequency does not change. Thus, the percentages in Table 3-8A are used for a 25 percent reduction in refuse collection.

3.8 ADJUSTING MODEL PROGRAM COSTS FOR SCALE

Thus far the costs (including avoided costs) of a model program in a model community of a specific size, i.e., population served, have been discussed.[23] Estimating the net costs of the materials separation requirement at the national level requires a method of extrapolating from model communities to communities of different sizes.

It is assumed that the costs of collection and post-collection processing for any particular combination of model program and population served class exhibit constant returns to scale. For example, in a community that is 10 percent larger than the corresponding model community,[24] the costs of the two-stream and multiple-stream programs would be 10 percent greater. This extrapolation is equivalent to using a piecewise linear function to approximate the average cost curve.

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[22] After exclusion of units below the size cutoff of 35 Mg/day of design capacity.
[23] This study uses the median of the population-served class (see Chapter 4).
[24] The comparison of population served takes into account the expansion of the catchment area.

CHAPTER 4

FRAMEWORK FOR ESTIMATING NATIONAL COSTS AND DIVERSION

The Agency's materials separation requirement defines the goal—25 percent of MSW—that owners and planners of MWCs must meet, but it does not prescribe a particular materials separation program, leaving the selection to the owner of the unit. Predicting the result of the materials separation requirement requires predicting the response of the owners[1] of MWCs. With the freedom that the proposed requirement gives, owners are likely to implement the requirement differently. Public involvement in curbside recycling programs may very well be a factor in the materials separation programs that MWC owners implement. Estimating the costs and effectiveness of these programs requires predicting the response of the public. The modeling framework therefore links differences in the choices among programs made by the owners of MWCs and differences in the public's response to differences in communities.

Existing and planned MWCs number almost 300. This number is too large to allow us to attend to more than a few of the influences on an owner's choice of materials separation program. It is hypothesized that differences in choice of program correlate with differences in the size of population served and population density of the MWC service area. Thus the type of community is again the critical determinant of behavior. Recall from Chapter 2 that the type of community also influenced the prediction of the diversion by consumers of materials from the residential waste stream.

Section 4.1 describes the procedure for creating a model community by estimating population served and population density for existing and planned MWCs. Section 4.2 defines the model communities that represent the catchment areas of actual and planned MWCs. Finally, Section 4.3 predicts the adoption of materials separation programs.

4.1 EXISTING AND PLANNED MWCS

This study describes a model community by its population served and population density. The available databases on MWCs do not contain these statistics. As explained in the next section, population served and population density are estimated for an existing MWC using the design capacity of the unit and the size of its catchment area; for a

[1] The term "owner" is used to refer to both actual owners of MWCs and planned owners.

planned MWC, a somewhat different procedure is used. These estimates depend on the location, capacity, and operational status of MWCs.

Table 4-1 identifies the existing MWCs, giving location by city and state, design capacity, and start-up date. Different sources of information[2] disagreed on the number and operational status of units, so these sources were merged to lessen the chance of overlooking an MWC. Two hundred thirteen units are already in service or will be in service sometime in 1991.[3] These units are listed in increasing order of design capacity in Table 4-1.

The planned MWCs included in this analysis replicate the 12 model units that appear in the economic impact analysis of the New Source Performance Standards for air pollutant emissions from MWCs (see Table 4-2). Other lists of planned units are available but were not used because of the difficulties that would have arisen in estimating the cost savings from the construction and operation of smaller, planned units. The capital, operating, and maintenance costs of the model MWCs are known precisely. The use of model, planned MWCs allows a more accurate estimate of the cost-savings from downsizing.

Corresponding to each model MWC is a scaling factor (in the NSPS economic impact analysis) that gives the expected number of units. The scaling factors are fractional numbers. They were converted to whole numbers to match the list of existing MWCs.[4] Thus, this analysis develops measures of cost and effectiveness for materials separation programs implemented by the owners of 17 small mass-burn/waterwall MWCs, 8 mid-size mass-burn/waterwall MWCs, and similarly for a total of 67 planned MWCs.

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[2] The sources are the October 1989 *City Currents; 1988-90 Resource Recovery Yearbook;* and "Waste Age 1989 Refuse and Incineration Refuse-To-Energy Listings," *Waste Age*, November 1989, pp. 169-182.

[3] A unit that will be in service in 1990 or 1991 is probably too nearly completely constructed to be redesigned. The response of an owner of a planned unit to the materials separation requirement should be the same as the response of an owner of an existing unit. Therefore, such planned units are included with actually existing units.

[4] The objective of keeping the total of model MWCs to 67 guided the conversion of scaling factors to integers. First a scaling factor was rounded to the nearest integer, thus producing a total of 65 MWCs; then the number 2 was added to the calculation.

TABLE 4-1. EXISTING MUNICIPAL WASTE COMBUSTORS

City	State	Design Capacity (Mg/Day)	Start-up Date
Auburn	NH	5	1979
Friday Harbor	WA	5	1978
Nottingham	NH	7	1972
East Penn Township	PA	7	1988
Canterbury	NH	9	NA
Stamford	VT	9	1973
Skaneateles	NY	12	1975
Gatesville	TX	12	1980
Grimes County	TX	12	1984
Harpswell	ME	13	1975
Candia	NH	14	NA
Plymouth	NH	15	1976
Wolfeboro	NH	15	1975
Shemya	AK	18	1975
Litchfield	NH	20	NA
Groveton	NH	22	1980
Sitka	AK	23	1985
Huntsville	TX	23	1984
Palestine	TX	23	1980
Wilton	NH	27	1979
Meredith	NH	28	NA
Hope	AR	34	NA
Mayport Naval Station	FL	36	1978
Carthage City	TX	36	1985
Collegeville	MN	39	1981
Pittsfield	NH	44	NA
Elkhart Lake	WI	44	1969
Westmoreland County	PA	45	1987
Ketchikan	AK	45	1991
Frenchville	ME	45	1984
Wrightsville	NC	45	1981
Brookings	OR	45	1978
Johnsonville	SC	45	NA
Hohenwald	TN	45	1988
Osceola	AR	45	1980
Waxahachie	TX	45	1982
Burley (Cassia County)	ID	45	1982
Galax	VA	51	1986
Stuttgart	AR	54	1980
Lewisburg	TN	54	1980
Savage	MN	62	1981
Juneau	AK	63	1986
Blytheville	AR	63	1983
Thief River Falls	MN	63	1985

CONTINUED

TABLE 4-1. EXISTING MUNICIPAL WASTE COMBUSTORS (CONTINUED)

City	State	Design Capacity (Mg/Day)	Start-up Date
Alexandria (Douglas County)	MN	65	1987
Livingston	MT	68	1982
City of Red Wing	MN	65	1982
Franklin	KY	68	1986
Port Washington	WI	68	1965
Fort Leonard Wood	MO	68	1981
Polk County	MN	73	1988
Ft. Dix	NJ	73	1986
Barron County	WI	73	1986
Hereford	TX	82	1965
Moore County	TX	82	1972
City of Fergus Falls	MN	84	1988
Bellingham	WA	91	1986
Marquette County	MI	91	1991
Durham	NH	98	1980
Prudoe Bay	AK	91	1981
N. Little Rock	AR	91	1977
Dyersburg	TN	91	1980
Harrisonburg	VA	91	1982
Salem	VA	91	1978
Batesville	AR	91	1981
Hot Springs	AR	94	NA
Miami	OK	98	1982
Windham	CT	98	1981
Cleburne	TX	104	1986
New Richmond (St. Croix Co)	WI	104	1988
Cuba (Cattaraugus Co.)	NY	102	1983
Perham (Quadrant)	MN	105	1986
Mandeville	LA	109	1991
Muscoda	WI	113	1989
New Canaan	CT	113	1971
Coos Bay	OR	113	1976
Key West (Monroe Co.)	FL	136	1986
Pascagoula	MS	136	1985
Craighead County	AR	136	1991
Humboldt	TN	136	1990
Waukesha	WI	159	1971
Skagit County	WA	161	1988
Muskegon County	MI	163	1990
Oswego County (Volney)	NY	181	1986
Long Beach	NY	181	1988
Wilmington (New Hanover Co)	NC	181	1984
Gallatin	TN	181	1981
Claremont	NH	181	1987

CONTINUED

TABLE 4-1. EXISTING MUNICIPAL WASTE COMBUSTORS (CONTINUED)

City	State	Design Capacity (Mg/Day)	Start-up Date
Shreveport	LA	181	1987
Portsmouth	NH	181	1982
Euclid	OH	181	NA
Oneida County (Rome)	NY	181	1985
Hampton	VA	181	1980
Jackson County	MI	181	1987
Hampton	SC	218	1985
Rochester (Olmstead County)	MN	181	1987
Ames	IA	181	1975
Madison	TN	190	1988
Berkeley County	SC	204	NA
Middletown	CT	209	1991
Charlotte-Mecklenburg County	NC	212	1989
Pittsfield	MA	218	1981
Rutland	VT	218	1987
Sheboygan	WI	218	1965
Glen Cove	NY	227	1983
Easton	PA	272	1986
Tacoma	WA	272	1990
Lakeland	FL	272	1982
Tuscaloosa	AL	272	1984
Springfield	MA	327	1988
Harford County	MD	327	1988
Norfolk	VA	327	1967
City of Commerce (LA Co.)	CA	327	1987
Hudson Falls	NY	363	1990
Oyster Bay	NY	363	NA
Gaston County	NC	363	1991
Saratoga County	NY	363	1991
Washington County	NY	363	1991
Dutchess County	NY	363	1989
Duluth	MN	363	1986
La Crosse County	WI	363	1987
Davis County	UT	363	1988
Warren County	NJ	363	1988
Madison (Gas and Electric Co)	WI	363	1979
Wallingford	CT	381	1990
Webster	MA	381	1991
Huntington	NY	408	NA
Taunton	MA	408	1991
Framingham	MA	454	1970
Lisbon	CT	454	1991
Londonderry	NH	454	1991
Glendon	PA	454	1991

CONTINUED

TABLE 4-1. EXISTING MUNICIPAL WASTE COMBUSTORS (CONTINUED)

City	State	Design Capacity (Mg/Day)	Start-up Date
Portland	ME	454	1988
Concord	NH	454	1989
Savannah	GA	454	1987
Tacoma	WA	454	1989
Panama City (Bay County)	FL	463	1987
Islip	NY	470	1988
Lake County	FL	479	1991
Marion County	OR	499	1987
Stamford	CT	508	1974
Manchester	NH	508	1991
Gloucester County	NJ	522	1990
Fall River	MA	544	1972
Clinton Township	MI	544	1972
Preston	CT	544	1991
Oakland County	MI	544	1991
Biddeford/Saco	ME	544	1987
Wilmington (Pigeon Point)	DE	544	1986
Honolulu	HI	544	1970
Charleston	SC	544	1989
Albany (steam plant)	NY	544	1981
Kent County	MI	567	1990
Bristol	CT	590	1988
Huntsville	AL	626	1990
Somerset County	NJ	635	1991
Harrisburg	PA	653	1972
Albany (processing plant)	NY	680	1981
Bangor /Brewer	ME	680	1988
Johnston	RI	680	NA
Babylon	NY	680	1988
Eden Prarie	MN	726	1987
St. Louis	MO	726	NA
Pierce County	WA	726	1991
Stanislaus County	CA	726	1989
Oklahoma City	OK	744	1991
Lawrence	MA	862	1984
Alexandria/Arlington	VA	884	1988
Washington	DC	907	1972
Louisville	KY	907	1960
New York (Betts Avenue)	NY	907	1980
Wilmington	DE	907	1984
Tampa	FL	907	1985
Newport	MN	907	1987
Akron	OH	907	1979
Pasco County	FL	952	1991

CONTINUED

TABLE 4-1. EXISTING MUNICIPAL WASTE COMBUSTORS (CONTINUED)

City	State	Design Capacity (Mg/Day)	Start-up Date
Camden County	NJ	952	1991
Nashville	TN	1,016	1974
Tulsa	OK	1,020	1986
Pulaski	MD	1,088	1982
Cockeysville	MD	1,088	NA
Lancaster County	PA	1,088	1991
Hillsborough County	FL	1,088	1987
Hennepin County	MN	1,088	1989
Baltimore County	MD	1,088	NA
York Co. (Manchester Tnshp)	PA	1,219	1989
Long Beach	CA	1,252	NA
Millbury	MA	1,361	1988
Anoka County (Elk River)	MN	1,361	1989
Saugus	MA	1,361	1975
North Andover	MA	1,361	1985
Montgomery County	OH	1,361	1970
Chicago (NW)	IL	1,451	1989
Haverhill	MA	1,497	1989
Rochester	MA	1,723	1989
Portsmouth	VA	1,814	1988
West Palm Beach	FL	1,814	1989
Honolulu	HI	1,959	1990
Hartford	CT	1,814	1988
Niagra Falls	NY	1,814	1981
Columbus	OH	1,814	1983
Bucks County	PA	2,041	1991
Bridgeport	CT	2,041	1988
Westchester County	NY	2,041	1984
Delaware County	PA	2,438	1991
Essex County	NJ	2,041	1990
Baltimore (SW Rec. Fac.)	MD	2,041	1985
Hempstead	NY	2,103	NA
Indianapolis	IN	2,141	1989
Fairfax	VA	2,721	1990
Dade County	FL	2,721	1982
Pinellas County	FL	2,857	1983
Detroit	MI	2,993	1990

Source: *City Currents* Volume 8, Number 3, October 1989; *1988-89 Resource Recovery Yearbook*; and *Waste Age*, November 1989, "Waste Age 1989 Refuse and Incineration Refuse-to-Energy Listings," pp. 169-182.

TABLE 4-2. CHARACTERISTICS OF MODEL MWCs

Model Unit #	Abbreviated Term	Definition of Term	Model Unit Capacity (Mg/Day)	Scaling Factor	Number Used in This Study[a]	Assumed Population Served Per Unit[a]
1	MB/WW (small)	Mass Burn/Waterwall (small)	180	16.81	17	93,903
2	MB/WW (mid-size)	Mass Burn/Waterwall (mid-size)	730	7.28	8	380,831
3	MB/WW (large)	Mass Burn/Waterwall (large)	2,040	8.49	9	1,064,239
4	MB/REF	Mass Burn/Refractory Wall	450	3.24	3	234,759
5	MB/RC	Mass Burn/Rotary Combustor	950	3.24	3	495,602
6	RDF	Refuse Derived Fuel	1,810	5.39	5	921,955
7	RDF/CF	Refuse Derived Fuel/Co-fired	1,810	3.31	3	460,977
8	MOD/EA	Modular/Excess Air	220	3.35	3	110,706
9	MOD/SA (small)	Modular/Starved Air (small)	45	1.80	2	22,644
10	MOD/SA (mid-size)	Modular/Starved Air (mid-size)	90	7.13	7	45,289
11	FBC/BB	Fluidized Bed Combustion (Bubbling Bed)	820	2.06	2	417,681
12	FBC/CB	Fluidized Bed Combustion (Circulating)	820	4.54	5	417,681
		TOTAL		66.64	67	

[a]Calculated in this study.

Source: Morris et al. 1989 (Tables 3-2 and 5-8).

4.2 MODEL COMMUNITIES

Several model communities that represent the catchment areas of actual and planned MWCs are needed to create a manageable analytical framework. The model communities differ by population served and population density. They also differ in other ways, for example, by the percentage of single-family residences, but population served and density determine these differences. Table 4-3 classifies the model communities. The population-served variable has four levels, and the population-density variable, three levels. Instead of using the 12 possible combinations of population served and population density, the study uses the 7 that are of most interest to the Agency.

TABLE 4-3. CLASSIFICATION OF MODEL COMMUNITIES

Model Community	Population	Population Density
A	Very Small	Low
B	Very Small	Medium
C	Small	Low
D	Small	Medium
E	Medium	Medium
F	High	Medium
G	High	High

The modeling framework is operational because specific values for the population served and density variables were selected. The selection process involved several steps, and, because the modeling of the planned MWCs in the economic impact analysis excludes location, the steps for the existing and planned units differ slightly. Briefly, the steps are the following:

1. For every MWC, estimate the population served.
2. For every existing MWC, determine the location (county, city, or Primary Metropolitan Statistical Area) of the catchment area.
3. For every existing MWC, determine the density of the catchment area.
4. Determine the ranges for the population-served and density classes.

5. For every existing MWC, use actual population served and catchment area density to assign the unit to the appropriate population-served and density classes.

6. For every planned MWC, use actual population served to assign the unit to the appropriate population-served class.

7. For every planned MWC, randomly assign the unit to either a medium or high density class.

Most of these steps were complex and are described in the remainder of this subsection. The fifth and sixth steps were omitted because of their mechanical nature.

4.2.1 Population Served

Population served means the "full-garbage-equivalent" population served: the population served that results under the twin assumptions that all of someone's garbage goes to an MWC and that everyone sends his or her garbage to the MWC. The crucial elements in the calculation of population served are the capacity utilization factor and the per capita generation of MSW. The formula for calculating population served is:[5]

Population Served = capacity * 2000 * capacity utilization factor/MSW generation (4-1)

The rationale for this formula is the equality between expected service demanded (total flow of MSW to the unit) and service provided, including an adjustment for desired excess capacity (design capacity times capacity utilization factor).

Recall that the capacity of an MWC was obtained from either published surveys or the NSPS economic impact analysis. The actual capacity utilization factor for an existing MWC was used if the unit's owner reported it in a §114 letter; if not, then a factor was assumed. For the latter MWCs and for all planned MWCs, these capacity utilization factors were used: mass burn—0.85, RDF and FBC—0.83, modular—0.82, unknown technology—0.83.[6]

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[5] The unit of capacity is tons per day; the capacity utilization factor is a number less than one; the unit of MSW generation is pounds per person per day.

[6] The source of the factors is the NSPS economic impact analysis (p. xvi). The unknown technology class refers only to existing MWCs.

This study uses 3.58 pounds per person per day for the generation rate.[7] This rate is commonly cited and used for planning purposes. The Agency refers to it in the proposed standards for new MWCs. [8](A confidence interval for this point estimate is unavailable, which is unfortunate because estimates of MSW generation are subject to a large measurement error.[9] For example, the results of the *BioCycle* 1989 survey of state recycling and composting indicate that the annual generation of MSW is between 268 million and 270.5 million tons (Glenn, 1990, p. 48), implying a per capita rate of approximately six pounds per person. These estimates exceed Franklin Associates' estimate by almost 70 percent, although some (the amount is unknown) of the difference is due to different definitions of MSW. In view of the magnitude of these differences, it is important to discuss at the outset the effects on this investigation of using either another per capita generation rate or an alternative to the full-garbage-equivalent assumption.

Changing the per capita generation rate will not change the estimates of the quantity of materials diverted from MWCs, but the change in cost is ambiguous because of opposite tendencies. The formula (4-1) for population served implies that a change in per capita generation leads to an offsetting change in population served: for any given capacity, if the generation rate were to increase by 70 percent, the population served would decrease by 70 percent. The following formula shows that diversion would not change:

$$\left[\sum_{\substack{\text{target} \\ \text{materials}}} (\text{Waste Composition Fraction}_i \ * \ \text{Participation Rate}_i \ * \ \text{Capture Rate}_i \ * \ (1 - \text{Residual Rate}_i)) \right] \ * \ \text{Per Capita Residual MSW} \ * \ \text{Population} \qquad (4\text{-}2)$$

Apart from the national average per capita generation rate, another issue is the assumption that all of someone's household MSW goes to an MWC. If the MSW in a community is delivered first to a transfer station and later sent to a landfill and an MWC, then the full-garbage-equivalent assumption is incorrect. In this community, distinguishing residents by disposal site is impossible. Analytically, a fraction of each resident's MSW goes to the MWC and the remainder to the landfill; the split depends on the relative flows. If 70 percent were to go to the landfill and 30 percent to the MWC,

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[7] The original reference for this particular rate of gross discards is Table 7 in Franklin Associates (1988, p. 21).

[8] U. S. Environmental Protection Agency. December 20, 1989 *Federal Register*.

[9] "The figure is a soft, even spongy number" (Glenn 1990, p. 48).

then the population served would be the entire population of the community, and, as regards the flow to the MWC, the per capita generation rate would be 30 percent of the average for the entire community.

For the entire nation, the application of this alternative approach implies that the population served by all existing MWCs equals the national population less the population served exclusively by landfills. The full-garbage-equivalent assumption used should imply a smaller population served.

The preferred approach uses the full-garbage-equivalent assumption because the alternative requires tracking flows of MSW to every MWC and landfill community by community. The preferred approach is tractable.

4.2.2 Location of the Catchment Area

This study uses the 1988-89 version of the *Resource Recovery Yearbook* as an initial guide to the catchment areas of existing MWCs. The *Yearbook* specifies only one city, one county, several cities, or more than one county for the catchment area, but does not name them. The location of the MWC approximates the actual cities or counties included in the catchment areas.

If the *Yearbook* states that only one city or one county comprises the catchment area for an MWC, the catchment area was defined in that manner. If the *Yearbook* states that more than one city or county are included in the catchment area, however, Primary Metropolitan Statistical Areas (PMSAs) were used as a guide to the catchment area.

If an MWC is in or near a PMSA, it is assumed that the MWC served that PMSA. The assumption satisfies the several-city or several-county catchment area specified by the *Yearbook* because PMSAs typically consist of more than one city and extend into multiple counties. If the MWC is not near a PMSA, and the catchment area described in the *Yearbook* consists of either several cities or more than one county, the catchment area was determined to be the county of the MWC. Although the catchment area for this MWC could lie in multiple counties, the other counties could not be determined.

4.2.3 Density

Density affects participation rates in high population catchment areas (see Table 2-8) and the cost of materials separation programs. The latter effect is due to differences in land and labor costs, the relative frequency of single-family households,[10] and collection efficiencies.[11] Density is an indicator of these differences, but density per se is not a variable in the model used to estimate the costs of materials separation programs.

The calculation of "density" divides the total population served[12] in a catchment area by its land area. This measurement approximates, but is different from, the actual density of a catchment area. Actual density is unavailable because adequate information on catchment area is not available; consequently, a substitute is used.

4.2.4 Population-Served and Density Classes

The histograms of population served and density for existing MWCs were used to determine the ranges of the population and density classes. The number of classes was decided in advance,[13] and obvious breakpoints were not found. Ranges were chosen that were expected to possess both a good spread in the medians and enough MWCs to justify the class. However inexact the procedure, the results are satisfactory. Table 4-4 describes the population and density classes.

4.2.5 Assumed Density of Planned MWCs

Planned MWCs were randomly assigned to medium and high density classes. The rationale is that planned MWCs are very unlikely to service low density catchment areas, while existing MWCs servicing medium and high density catchment areas are almost equally numerous (a pattern that is expected to continue).

4.2.6 Summary

Table 4-5 characterizes the model communities. This study estimates the cost of a particular model materials separation program in a model community by using a specific population served: 7,000; 53,000; 164,000; or 462,000.[14] The per capita

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10 The trucks, crew, and containers making up a collection system vary with the type of residential unit.

11 The measure of collection efficiency is the number of households serviced per hour. It equals the product of stops per hour and households per stop. Collection efficiency varies across the urban, suburban, and rural regions within a catchment area; it also varies with the type of residential unit serviced (single-family or apartment house).

12 When multiple MWCs service the same catchment area, the populations served were summed.

13 There are four classes for population and three for density.

14 The Waste Plan model requires an input that is a multiple of 1000, hence, the slight departure from the medians of the population served classes.

TABLE 4-4. POPULATION SERVED AND DENSITY CLASSES: RANGES, MEDIANS, AND NUMBER OF OBSERVATIONS

Population	Range	Median	Number of MWCs
Served Class			
Very Small	$P \leq 20{,}000$	7,196	30
Small	$20{,}001 \leq P \leq 100{,}000$	53,212	95
Medium	$100{,}001 \leq P \leq 200{,}000$	164,313	32
High	$200{,}000 \leq P$	462,011	123
Density Class			
Low	$D \leq 400$	95	122[a]
Medium	$401 \leq D \leq 800$	464	35[a]
High	$801 \leq D$	2,043	40[a]

[a]Number of existing MWCs.

TABLE 4-5. DESCRIPTION OF MODEL COMMUNITIES

	Range	Waste Plan Input
Population Served		
VS	$P \leq 20{,}000$	7,000
S	$20{,}001 \leq 100{,}000$	53,000
M	$100{,}001 \leq P \leq 200{,}000$	164,000
H	$200{,}001 \leq P$	462,000
Density (persons/square mile)		
L	$D \leq 400$	
M	$401 \leq D \leq 800$	
H	$801 \leq D$	

Per capita MSW generation		***Single-family units (percent)***	
Residential	2.37 lbs./day	L density	90
Total	3.58 lbs./day	M density	75
		H density	55

generation rate and density have already been discussed. The additional characteristics of the model communities, namely the division of MSW generation between residential and other sources, and the relative frequency of single-family households, need discussion.

The residential fraction of MSW was estimated using Westat's survey of municipal landfills (U.S. Environmental Protection Agency, 1988b), under the assumption that "household wastes" and "commercial wastes" are MSW: 113.86 million tons and 58.17 million tons annually, respectively (Ibid., p. 7-3). These figures imply that 66 percent of landfilled MSW is generated by residential sources. It is assumed that 66 percent of all MSW, however disposed, is generated by residential sources. Then, using Franklin Associates' estimate of total per capita generation (3.58 lbs/person/day), 66 percent or 2.37 lbs/person/day of MSW is the residential rate.

The housing parameters were defined by surveying the information on housing reported in the *County and City Data Book.* This reference gives the percentage of year-round housing units with five or more units, from which the percentage of single-family units is inferred as one minus the former statistic. Durham, North Carolina, was considered a typical medium density catchment area: single-family units (in 1980) accounted for approximately 74 percent (U.S. Bureau of the Census, 1988, p. 692). This percentage was the anchor for selecting the percentages for the low and high density model communities: 90 percent and 55 percent, respectively. Evidence for the plausibility of these percentages comes from a comparison with housing statistics in actual cities.[15]

4.3 ASSIGNING MODEL PROGRAMS TO MODEL COMMUNITIES

The proposed rule mandates a level of performance for a materials separation program and the separation of certain materials, but these requirements together far from prescribe an acceptable program. The list of targeted materials is a loose constraint: given the conditions in secondary materials markets, any materials separation program for MSW would collect paper, beverage containers, etc.[16] Owners of MWCs are free to choose most of the critical elements of design:

- the point where materials separation occurs
- the collection system
- the materials recovery facility or recycling transfer facility

[15] The percentage of single-family units in boroughs of New York range from 2.5 percent (Manhattan) to 57 percent (Queens), and the figure for Seattle is 67 percent. At the other extreme, the figure for Suffolk, Virginia (125 persons/square mile) is 96 percent, and for Oak Ridge, Tennessee (324 persons/square mile) 84 percent of units are single-family (U.S., Bureau of Census, 1988, *passim*).

[16] The 10 percent cap on credit for yard waste appears to be a binding constraint (see Chapter 6).

- the extent of post-collection processing
- the buyer of secondary materials
- the quality of promotional services
- the incentives for household participation

The above characteristics along with the smaller details, previously described in Chapter 2, ignore the issue of integrating the materials separation program with other components of a solid waste management system and the issue of coordination. Larger issues, which an owner could address in the selection of an optimal materials separation program, are the following:

- geographical scope—which may allow combined programs to take advantage of technological economies of scale;

- cooperative marketing—the benefits of which may be higher prices and more reliable sales;

- waste reduction—which under the proposed rule is equivalent in effect to materials separation; and

- optimal redesign of a planned MWC—which occurs through simultaneously selecting the size of an MWC and materials separation program.

The final group of considerations relevant to the optimal selection of a program pertains to the dynamics of secondary materials markets. These dynamics are important:

- the initial decline in prices as supplies increase
- future prices
- price variability
- technical standards for contamination of post-consumer materials

Technical standards for contamination, by influencing post-collection processing, help determine the design of the processing facility. The first three considerations will probably influence the financing of materials separation programs and thus also the selection of equipment for the collection system and processing facility. In addition, these considerations influence the attractiveness of strategies in adapting to market uncertainty[17] and thereby influence price.

Predicting responses to the proposed materials separation requirement is challenging. Two alternative approaches can be used to make predictions: simulate the relevant decision process or extrapolate from past trends.

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[17] Examples are buffer stocks and contracts between sellers and buyers of secondary materials.

The first approach would simulate the decision of the MWC owner concerning how he or she will comply. The success of this approach depends on either surveying owners to elicit information on their intentions vis-à-vis the requirement, or justifying an analogy with past modeling of the behavior of this type of decision-maker. A survey was beyond the scope of this study. The second option for formally modeling the decision process was evaluated by reviewing Mathtech's econometric model of the choice between constructing a municipal solid waste landfill and constructing an MWC (Bentley and Spitz, 1988). The model shows that cost is a determining factor, but not the only factor—the others are the educational level of the population served and the size of the manufacturing sector. Although the latter variables could serve as a proxy for land costs (Ibid., p. 17), they are in fact nonpecuniary variables and thus could serve as a proxy for variables that are significant in the political aspects of solid waste management. Nonpecuniary considerations or political constraints are relevant to planning curbside recycling programs but could not be quantitatively studied at this time.

Nonetheless, because costs are salient, one could attempt to approximate the decision process by assuming that only costs matter and that the decision-maker chooses the least costly option for compliance with the New Source Performance Standards or Emission Guidelines.[18] This description of decision-making in the context of solid waste management is difficult to justify. One observer, who is familiar with municipal planning because of his experience with rating municipal bonds, has remarked that "price and cost analysis of [recycling] programs of the local level appear not very sophisticated" (Medioli, 1990, p. 11). Decision theory also supports the view that minimization or global optimization is a misleading premise upon which to build a model of actual decision-making in complex and uncertain environments, such as solid waste management. As argued by Herbert Simon, people "satisfice."[19] "While economic man maximizes—selects the best alternative from among all those available to him; his cousin, whom we shall call administrative man, satisfices—looks for a course of action that is satisfactory or 'good enough'" (Simon 1961, p. xxv). Also, actual people selectively attend to features of the environment, forming a mental representation that is a gross simplification. A prediction of the outcome of an actual choice should be predicated on knowledge of how the decision-maker is likely to perceive the opportunity set. Although

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[18]Some way would also have to be found for justifying the delimitation of the opportunity set.
[19]The seminal works on this approach to behavior are "A Behavioral Model of Rational Choice" (Simon, 1955) and "Rational Choice and the Structure of the Environment" (Simon, 1956).

formal modeling of the decision process vis-à-vis compliance with the NSPS and EG could be very informative, it is unlikely to be successful at this time.

Consequently, an alternative approach was employed, which hypothesizes that the pattern of materials separation programs in the near future resembles the current pattern. Over short periods of time continuity can be observed in the economy; factors that have led to current patterns of behavior reoccur in the near future. The particular resemblance concerns the relative popularity of different curbside set-out methods.

Recent surveys of recycling programs (see Chapter 2) contain information on set-out methods. They provide rough guidance on the proportions of different programs, but neither one randomly selected respondents.[20] The lack of randomness in the sampling procedure is most evident in the Institute for Local Self Reliance survey, which selected respondents because of a program's success. Although calculating the percentage of programs that employ the same method is possible with the survey, the percentage is not an estimate of the percentage in the population of all programs. The following pattern seems representative:

- One-stream programs are very infrequent;
- The frequency of multiple-stream programs declines with population-served and/or density; and
- The frequency of two-stream programs increases with population-served and/or density.

Table 4-6 presents one prediction of the relative frequency of the materials separation programs that the proposed rule will probably foster. All programs are either two- or multiple-stream. Only two-stream programs are assigned to high density communities. Multiple-stream programs are most frequent in low density communities.

All 280 MWCs were randomly assigned to model programs to produce the assignment shown by Table 4-7. In each cell, the first upper figure is the total number of MWCs corresponding to that combination of community and program, the upper figure in parentheses is the number of planned MWCs, and the lower figure is the total population-served (before expansion of the catchment areas of existing MWCs). Table 4-7 therefore indicates the distribution of MWCs by program and community in the absence of exclusions.

[20]This remark is not a criticism. It is an observation of a feature that affects the use of a survey.

Table 4-8 indicates the distribution of MWCs by program and community after the exclusion of MWCs that either fall below the size cutoff (35 MgPD) or are located in an area in which baseline materials separation will be sufficient for compliance with the Agency's requirement. As explained in Chapter 2, these areas are Connecticut, the District of Columbia, Florida, Louisiana, Minnesota, North Carolina, New Jersey, Ohio, Virginia, and Washington. The population indicated in this table is effective population, (i.e., the population after expansion of a catchment area).[21] One-hundred ninety three of 280 MWCs remain after exclusion.

TABLE 4-6. PREDICTED CHOICE OF MATERIALS SEPARATION PROGRAMS, BY COMMUNITY TYPE (%)

	Community (population-served/density)						
Program Option	**A (VS/L)**	**B (VS/M)**	**C (S/L)**	**D (S/M)**	**E (M/M)**	**F (H/M)**	**G (H/H)**
Two-stream option 1	0	60	0	60	60	60	70
Two-stream option 2	20	20	20	20	20	20	30
Multiple-stream	80	20	80	20	20	20	0
Total	100	100	100	100	100	100	100

[21] The results reported in Chapter 6 are based on effective population.

TABLE 4-7. NUMBER OF EXISTING AND PLANNED MWCs ASSIGNED TO MODEL PROGRAMS AND COMMUNITIES (ALL MWCs INCLUDED)

	Community (population-served/density)						
Program Option	A (VS/L)	B (VS/M)	C (S/L)	D (S/M)	E (M/M)	F (H/M)	G (H/H)
Two-stream option 1							
Number of MWCs	0	7 (0)	0	23 (16)	19 (0)	40 (10)	40 (19)
Population served[a]	0	93,770	0	1,552,496	3,637,344	22,615,904	28,736,903
Two-stream option 2							
Number of MWCs	4 (0)	2 (0)	11 (0)	8 (4)	6 (1)	13 (1)	17 (6)
Population served[a]	30,728	12,389	845,331	575,932	1,112,753	8,441,066	14,818,662
Multiple-stream							
Number of MWCs	15 (0)	2 (0)	45 (0)	8 (6)	7 (2)	13 (2)	0
Population served[a]	186,314	10,241	2,915,443	652,280	1,108,790	7,776,204	0

[a] Before expansion of catchment area by existing MWCs.
Note: Number in parentheses is the number of total MWCs that are planned, not existing.

TABLE 4-8. NUMBER OF EXISTING AND PLANNED MWCs ASSIGNED TO MODEL PROGRAMS AND COMMUNITIES AFTER EXCLUSIONS BASED ON SIZE AND BASELINE MATERIALS SEPARATION

	Community (effective population-served/density)						
Program Option	A (VS/L)	B (VS/M)	C (S/L)	D (S/M)	E (M/M)	F (H/M)	G (H/H)
Two-stream option 1							
Number of MWCs	0	0	0	20 (16)	14 (0)	28 (10)	35 (19)
Population served[a]	0	0	0	1,281,063	2,712,369	15,868,693	24,273,217
Two-stream option 2							
Number of MWCs	1 (0)	0	11 (0)	6 (4)	5 (1)	7 (1)	12 (6)
Population served[a]	17,457	0	845,331	508,431	978,247	3,894,257	9,848,315
Multiple-stream							
Number of MWCs	3 (0)	0	30 (0)	6 (6)	5 (2)	10 (2)	0
Population served[a]	61,117	0	1,792,547	563,421	656,316	4,702,612	0

[a] After expansion of catchment area by existing MWCs.
Note: Number in parentheses is the number of total MWCs that are planned, not existing.

CHAPTER 5
MARKET IMPACTS OF A MATERIALS SEPARATION REQUIREMENT

Secondary materials of various kinds suitable for recycling are produced at several stages in manufacturing and consumption. "Prompt" scrap is pre-consumer scrap commonly recovered and recycled by producers during manufacturing processes as a way to reduce materials procurement and disposal costs. Some of this pre-consumer scrap enters formal secondary materials markets. Other "prompt" scrap is simply reintroduced into the production process, frequently in the same facility where it is generated.

Secondary materials are also present in the municipal solid waste (MSW) stream. Currently, some of these materials are recycled back into new products, though most is simply disposed of through landfilling or incineration. A materials separation requirement will increase the quantities of secondary materials recovered from the MSW stream. The sale of these materials has the potential to offset some of the costs of the requirement. The revenues earned from these sales are simply the quantities recovered times the prices received.

Conventional economic reasoning argues that increases in the supply of a commodity will, holding all else constant, lower the commodity's price. This chapter examines the potential effect of a materials separation requirement on the price of each of the five post-consumer secondary materials: newspaper, glass containers, aluminum containers, steel containers, and plastic containers. Projected post-materials separation requirement secondary materials prices presented in this chapter are used in Chapter 6 to estimate the annualized net cost of the materials separation requirement. These price reductions are important because, unless they are accounted for, sales revenues will be overstated and the costs of the materials separation requirement will be understated.

Post-residential consumer secondary materials (hereafter secondary materials) may be collected from households as mixed MSW, commingled recyclables, or separated recyclables. The form in which they are collected influences in part the magnitude and distribution of the pecuniary costs of recycling.

The recovery of secondary materials from mixed MSW involves the removal of specific materials like glass and metal from ordinary MSW at a materials recovery facility. This process imposes little recycling effort on consumers, but costs incurred at the facility per unit of recovered secondary material are relatively high because of the high degree of contamination.

Commingled recyclables are normally produced by households who separate, for example, glass and aluminum from their household waste stream. The glass and aluminum in the commingled state are collected and transported to a recycling facility where they are then separated. Commingled recycling involves more effort by households than ordinary MSW handling, but less pecuniary separating and recovery costs than mixed MSW handling.

Separated recyclables are produced by households who separate individual recyclable materials. Materials such as paper, aluminum, ferrous cans, glass, and plastic that have been separated by consumers are less expensive to process down-stream because they are relatively uncontaminated. Indeed, glass is commonly sorted by color, and newspaper may be separated from other paper. The pecuniary unit-cost of processing a separated secondary material is generally lower than that of processing a mixed- or commingled-source secondary material.

As implied above, the preparation of secondary materials for market requires different technologies that depend in large part on the form in which they have been collected. Mixed MSW-handling facilities are complex, multi-process facilities with high operating and maintenance costs (relative to commingled and separated facilities). Mixed MSW-handling is reportedly unpopular in the United States due to a history of poor performance in the 1970's. Commingled and separated recyclables processing is relatively simple and inexpensive.

The actual conversion of secondary materials into new products involves a wide range of industry-specific activities. For example, the processes involved in turning secondary newsprint into paperboard products are very different from those involved in turning secondary ferrous cans into new rolled steel products. Regardless of the industry or process, recycling at the "production level," where recycled material is combined with other inputs to produce a "final good," is not a costless process. The resource user will choose between newly extracted resources and recycled resources on the basis of relative cost. For example, since the unit price of silica sand is relatively low, cullet (waste glass) prices must remain low to compete. Glass manufacturers commonly have the flexibility to use as little as 10 percent and as much as 80 percent cullet in their silica-cullet mix and will determine the mix largely based on relative prices.

5.1 COMPARATIVE STATICS OF A MATERIALS SEPARATION REQUIREMENT

Because recycling involves at least three generically-different types of activities (collection, preparation, and manufacturing), clearly several or more markets might be affected by a materials separation requirement. Conceptually, prices and quantities of many goods and services could change, if only slightly. Beverages, silica sand, bauxite, pulpwood, and iron ore are only some of the products whose prices and quantities could change as a result of a materials separation requirement. This section describes qualitatively the expected directions and magnitudes of changes in prices and quantities of only a *subset* of those goods.

Figure 5-1 is a competitive-market diagram illustrating some first-round effects of a materials separation requirement. The diagram depicts a single secondary materials market, the market for recycled glass jars and bottles, old newsprint, recycled aluminum cans, recycled plastic containers, or recycled ferrous cans. Currently some baseline (without materials separation requirement) derived demand curve (d) defines the quantity demanded of the secondary material per time period at various prices, other things held constant. The position and slope of the derived demand curve depend on demand conditions in one or more down-stream markets that buy the secondary material, the cost shares of the secondary material in producing those outputs, and the substitution potential between the secondary material (e.g., recycled glass) and other inputs (e.g., silica sand) in the production of those outputs (e.g., glass).

The baseline supply curve (s) defines the quantity of the secondary material supplied at various prices holding other things constant. In this context, its position and slope can be thought of as dependent on the number and characteristics of communities that currently recycle a particular secondary material. The supply curve is drawn intercepting the abscissa, which indicates that some positive quantity of secondary material is supplied to the market even at a zero or negative price. This conclusion is consistent with the observation that, in some communities, all of, or more than, the cost of secondary materials collection and preparation is offset by savings in ordinary municipal refuse collection and disposal costs.

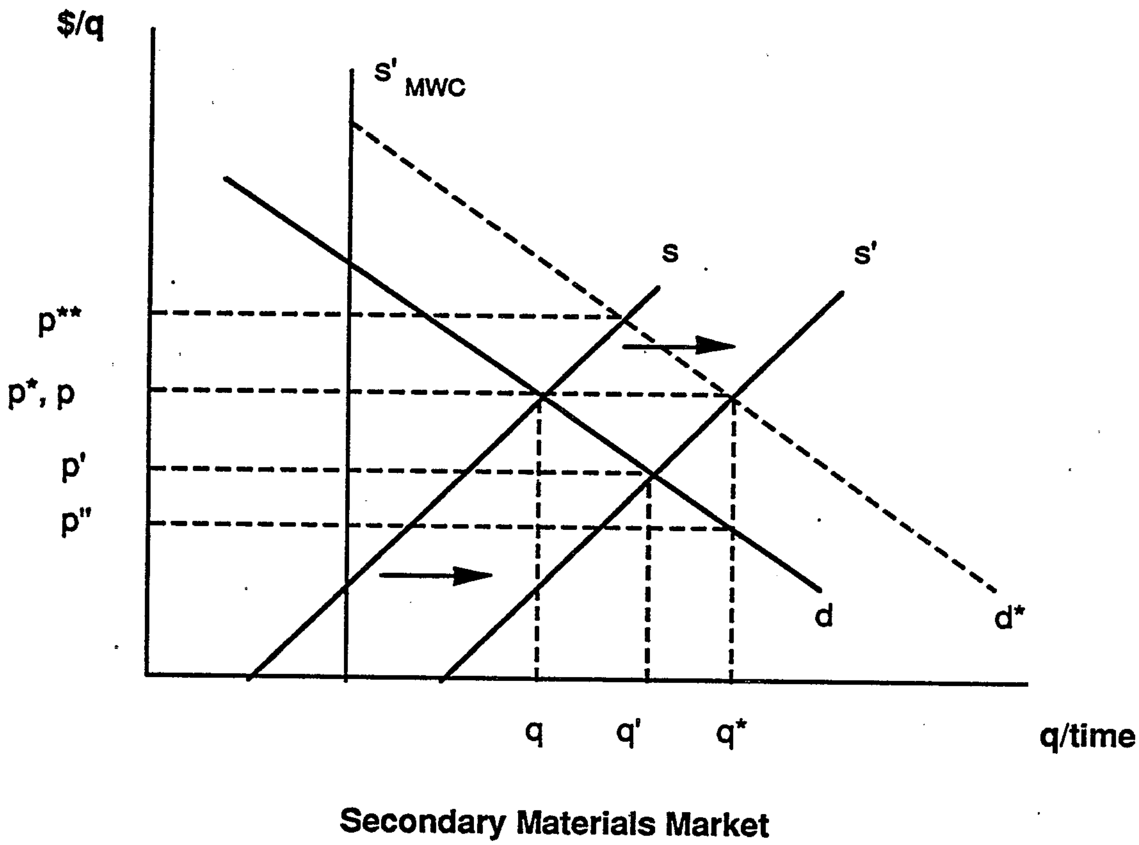

Figure 5-1. Market Impacts of a Materials Separation Requirement

To examine the potential impacts of a materials separation requirement in this market, it is assumed (as a simplification) that none of the 193 MWC communities currently recycle a given secondary material. The baseline secondary materials supply curve (s) from the intercept to the baseline demand curve (d) is comprised of communities other than the 193 MWC communities. Under this assumption, a materials separation requirement mandates the recovery in 193 "new" communities of some fraction of municipal waste in the form of one or more secondary materials. This new, exogenous supply is depicted in Figure 5-1 as the perfectly vertical (inelastic) supply curve s'_{mwc}, though this supply would probably not be completely insensitive to price as drawn.

The new (with materials separation requirement) market supply curve (s') is the horizontal summation of the baseline supply curve (s) and the 193 MWC community supply curve (s'_{mwc}). Given the stationary derived demand curve (d), the first-round equilibrium secondary material price and quantity is p' and q', respectively. Note that the new (with materials separation requirement) price is less than the baseline price, and that the new (with materials separation requirement) quantity is less than the simple sum of the baseline quantity and this exogenous new quantity. As long as buyers and sellers of a secondary material are at all sensitive to price, a materials separation requirement-induced supply increase will lead to a reduction in price and a net-increase in quantity less than the exogenous supply increase. Under these conditions, price must fall for the market to clear. Also under these conditions, the net-increase in quantity will be less than the exogenous increase in quantity because of "displacement"—the lower price will cause some marginal baseline recycling communities to recycle less.

Three factors influence the degree (absolute or relative) of first-round impact on price and quantity: the size of the exogenous shift in supply, the slope of the baseline supply curve, and the slope of the baseline derived-demand curve.

The exogenous supply shift is the quantity of "new" secondary material entering the market from the 193 MWC communities. It will depend largely on the quantity already being supplied (at baseline) by these 193 communities and their responsiveness to the regulation. All else being equal, greater exogenous shifts will result in lower equilibrium prices and greater equilibrium quantities.

The slope of the baseline supply curve (s) also influences the equilibrium impacts of a materials separation requirement. Given any downward-sloping derived demand curve (d) and exogenous supply shift (s'_{mwc}), the flatter (more elastic) the supply curve, the less the impact of the shift on equilibrium price and quantity. The explanation lies in the reason behind the slope. If the supply curve is relatively steep, the community recycling effort is relatively insensitive to the price of the secondary material. As price falls, marginal baseline recycling communities find it less profitable to recycle. The less sensitive these communities are to price (the steeper the supply curve), the fewer the number of communities that will curtail recycling efforts. At one extreme, when supply is perfectly inelastic (vertical), the equilibrium output change is equivalent to the exogenous shift because no baseline recycled output is "displaced" by new recycled output. Toward the other extreme, when supply is very elastic (flat), even a small reduction in price will lead many communities to curtail recycling, causing the equilibrium "net" recycling output to be a little higher than at the baseline.

Communities with baseline recycling programs will probably be reluctant to dismantle those programs, even in the face of reduced secondary materials prices. Starting and stopping recycling programs is not costless, especially since a program's success depends so greatly on public participation, which takes time to foster. Two consequences of such an outcome are important. First, communities that continue to operate voluntary (or other mandatory) recycling programs at reduced secondary materials prices will do so at lower profits (or greater losses) than before. Second, the equilibrium secondary material price (p') will be even lower than that depicted in Figure 5-1 if "unprofitable" programs are not curtailed. Indeed, if baseline recycling efforts continued unabated after a materials separation requirement, the secondary material price would fall to p" (given derived demand curve d).

Finally, the slope of the baseline demand curve (d) influences the equilibrium impacts of a materials separation requirement. Given any upward-sloping supply curve (s) and exogenous supply shift (s'_{mwc}), the flatter (more elastic) the demand curve, the lower the impact on equilibrium price while the impact on equilibrium quantity will be greater. If the demand curve is relatively "steep," buyers of the secondary material are relatively insensitive to price. As exogenous supply increases, the secondary material price falls. As price falls, buyers purchase little additional secondary material. Conversely, if buyers are very sensitive to price and demand is flat (elastic), even a small reduction in price will lead buyers to purchase significantly more secondary material.

The above analysis is a single-period impacts analysis. As a single-period analysis, a stationary baseline demand is assumed. Suppose that in the future demand for the secondary material increases from (d) to (d^*). This increase might occur in the old newspaper market as new de-inking capacity comes on line, and/or as demand for paper increases. Such a shift in derived demand effectively represents new buyers who "absorb" the additional supply forthcoming from new (MWC) communities and mitigate downward price impacts. In the special case drawn in Figure 5-1, the new equilibrium price (p^*) under the hypothetical future demand scenario is unchanged from the baseline price (p), and the new equilibrium quantity (q^*) is the sum of the baseline quantity (q) and the exogenous new supply. In this hypothetical inter-temporal analysis, price remains unchanged and quantity increases by the amount of the new supply forthcoming from MWC communities. More generally, a demand increase would lead to a post-materials separation requirement price higher than p' and a post-materials separation requirement quantity higher than q', holding all else in Figure 5-1 constant.

In addition, "displacement" of a different type may still occur under a materials separation requirement. In Figure 5-1, as derived demand shifts to the right along any upward-sloping stationary baseline supply curve, the secondary material price rises. As depicted, the equilibrium price at the intersection of the baseline supply curve (s) and the hypothetical future demand curve (d*) is p^{**}. At this higher price, more communities would find it economical to recycle, and output would increase beyond q even in the absence of a materials separation requirement. With a materials separation requirement in place, price would not rise to p^{**}, and some communities that would have voluntarily begun or expanded recycling efforts might no longer choose to. Instead, they would be "displaced" by the MWC communities. Possibly, some of the 193 MWC communities would be among the potential new entrants in the hypothetical future period so that the materials separation requirement is simply accelerating their recycling efforts. If this is true though, the exogenous supply shift would be less than depicted.

A materials separation requirement would also influence other markets. An output market purchases a secondary material (e.g., recycled glass) along with additional other inputs (e.g., silica sand, labor, energy) to produce a final or "more final" intermediate good (e.g., glass). Assuming there is some substitution potential between the secondary material and other inputs—as there is between recycled glass and cullet—a reduction in the price of the secondary material reduces the cost of producing the final output. If cost reductions are passed along to consumers, the quantity demanded of the final good increases.

The anticipated impacts in two hypothetical "other" markets should be considered: the market for a close substitute for the secondary material (e.g., bauxite for aluminum cans, or silica sand for recycled glass), and the market for some other, essentially non-substitutable input (e.g., fuel).

The signs as well as the magnitudes of price and quantity impacts in a substitute (primary materials) market are ambiguous. When the price of a secondary material (e.g., recycled glass) falls, two opposing forces are at work in a market for a substitute product (e.g., silica sand). On the one hand, because the two inputs are substitutes, an increase in the utilization of the secondary material *per unit output* of the final good allows a reduction in the utilization of the primary material *per unit output* of the final good. Put differently, the *substitution effect* reduces demand and, generally, price for the primary input. On the other hand, as explained above, a price reduction in the final good market leads to an increase in quantity demanded in the final good market. As producers of the final good produce more output to satisfy demand, they require more inputs. This result leads to an off-setting, positive *output effect* in the primary market. Whether the net effect in the substitute primary market is "positive" or "negative" is a function of demand and supply elasticities, substitution elasticities, and cost shares.

The signs, if not the magnitudes, of impacts in the market for a non-substitute input are relatively clear. A demand-induced increase in production in a final market prompted indirectly by a price reduction in a secondary material market will lead to a positive output effect in a market for some other, non-substitute input. Because there is no significant substitution effect to consider, the net effect is likely to be positive. Consequently, equilibrium prices and quantities in such markets will tend to rise as a result of a materials separation requirement.

5.2 PRELIMINARY ESTIMATES OF MARKET IMPACTS OF A MATERIALS SEPARATION REQUIREMENT

The estimates to be presented here result from a single-period analysis. They should be interpreted as preliminary estimates of equilibrium prices and quantities in each secondary material market with and without a materials separation requirement. Demand and supply shifts in these and related markets that might be expected to occur over time are not modeled. If, for example, the demands for secondary materials are generally increasing over time, they would tend to mitigate the projected price impacts of the materials separation requirement.

Also, the estimates result from an analysis that does not address potential interrelationships between secondary materials markets. For example, in reality a baseline recycling community's decision whether, how, and what to recycle depends partly on prices of old paper, old aluminum cans, old glass, etc. The baseline supply functions (supply elasticities) used in this analysis are assumed to be stable in this regard, but in reality they probably are not.

Tables 5-1 through 5-5 present price and quantity impact projections and the underlying parameter assumptions. The baseline quantity of each material is an estimate for 1990. The baseline price of each material is an estimate of the long-run equilibrium price in the absence of an MSR. Details on the estimates will be provided below. The elasticity of demand for post-consumer newspapers has been estimated by using Bingham and Chandran's (1990) model. Demand elasticities for the other four materials are assumed to be more elastic, as will be described below. The elasticity of supply of post-consumer newspapers has been estimated by Bingham and Chandran (1990). The supply elasticities for the other secondary materials are identical by assumption. The estimates of net diversion reflect the model recycling programs and communities described in previous chapters in this report. They exclude (do not count) materials already being recycled in the nine states and the District of Columbia that already comply with the materials separation requirement.

5.2.1 Post-Consumer Newspaper

Table 5-1 presents model parameter assumptions and impact projections in the post-consumer newspaper market.

Franklin (1990) estimates that 4.4 million tons of old newspaper (ONP) were recovered for recycling in 1988. The estimate is adjusted upward to the 1990 estimate reported in Table 5-1 (5.371 million tons) using national waste paper consumption data reported in the June 1990 Survey of Current Business.

Recycling Times (August 28, 1990) shows prices for baled material in large quantities, relatively free of contamination, freight not included, which is realistically the commodity being sold by municipalities. Prices during the first two weeks of August 1990 vary from -$40 to +$10 per ton, depending on the region.

The wastepaper Producer Price Index (PPI) has ranged from as low as 100 in 1982 to as high as 223.4 in 1984 (index 1982=100) (U. S. Department of Labor, Bureau of

Labor Statistics, June 1990). The current PPI for wastepaper is 141.0. Recognizing the limitations that the PPI is calculated using mill prices paid to dealers (not prices paid by dealers to municipalities) and is for all waste paper (not just old newspaper), it can be used to estimate the price received by municipalities in 1984. Assume that municipalities currently receive an average of $5 per ton for newspaper (the range is $-40 to $+5 per ton). Adjusting the 1984 price to 1990 dollars using the GNP price deflator, the 1984 price in 1990 dollars is $9.53.

McEntee (1990) reports that in New Jersey dealers charge $20 to $40 per ton to bale, process, and deliver old newspaper to a mill. The same article shows that in January 1985, loose (unbaled) old newspaper was about $5 per ton at the dealer's door in the New York city area. This figure allows us to estimate a *mill price* in the New York City area of $25 to $45 per ton (assuming the processing charge was about the same in 1985).

Waste Age (March, 1989) charts mill buying prices of old newspaper in Chicago from 1970 to 1989. It illustrates that "the market price for No. 1 news in June, 1988, was $45 per ton in the Chicago market. This is the mill buying price for old newspapers. If the paper packer provides a roll-off container for a recycling center, or a paper drive, the price paid to the collector would be about $12 per ton." At the other extreme, "if the collection center is equipped to prepare bales, the price for brokered tonnage would be $42 to $42.50 per ton."

Old newspaper prices have fluctuated greatly over time and across regions. Prices received by municipalities also apparently vary significantly depending on how they prepare the material for dealers. A range of $5 to $42 per ton received by municipalities for baled old newspaper is assumed as a long-run equilibrium price baseline, with a best estimate toward the lower end of the range: $10 per ton.

A model of North American pulp, paper, and other related markets (Bingham and Chandran, 1990) estimates that the long-run own-price demand elasticity for recycled newspapers is -0.71. Several reasons suggest that the demand elasticity for this good is in fact inelastic. The U. S. Congress Office of Technology Assessment (1989) reports that most new newsprint producing capacity now under construction in the U.S. will use virgin (not recycled) fiber. The report also indicates the following:

- world ONP supply is out-pacing demand;
- export prices are soft and the potential for increases of exports to Europe is low;

- users are concerned that "mandatory separation" ONP quality is low; and
- ONP prices appear to be extremely sensitive to supply shifts.

Further, the Bingham-Chandran model allows for the addition of de-inking capacity. If it did not, the demand elasticity would be even lower. Consequently, the demand elasticity employed in this analysis is -0.71.

The projected best-estimate equilibrium price of post-consumer newspapers following implementation of the materials separation requirement is $9.35 per ton—6.5 percent below baseline. Other impact estimates are presented in Table 5-1 as well.

5.2.2 Post-Consumer Glass

Table 5-2 presents model parameter assumptions and impact projections in the post-consumer glass market.

Franklin (1990) estimates that 1.5 million tons of post-consumer glass bottles were recovered for recycling in 1988. The estimate is adjusted upward to the 1990 estimate reported in Table 5-2—1.8 million tons—based solely on a report that one of the nation's largest glass-recycling firms recycled 20 percent more glass in 1989 than in 1988 (Powell, 1990). The estimate reported in Table 5-2 may be conservative.

Recycling Times (August 28, 1990) shows prices paid by dealers for used glass. Prices during the first two weeks of August 1990 vary from -$5 to +$100 per ton, depending on glass color and region. Across regions, $30 looks representative.

Waste Age (March, 1989) reports that the market price for cullet in May, 1988, was approximately $40 per ton *delivered to a glass plant* and color sorted. The price received by municipalities has to be lower than $40 because this is the *delivered* price. This report is consistent with the $30 estimate described above.

Recycling Today (July 16, 1990) reports that Ball-Incon Glass Container Corporation, which has 12 plants across the country, pays from $50 to $90 per ton for recycled glass, depending on the region. These are also *delivered* prices.

The same article in *Recycling Today* quotes a glass scrap dealer who reports that prices paid by glass companies have fallen from $80 to $50 per ton.

For this analysis, a range of $20 to $80 per ton received by municipalities for recycled glass containers is assumed as a baseline long-run equilibrium price, with a best estimate toward the lower end of the range: $30 per ton.

No published estimates of the own-price demand elasticity for recycled glass containers are known to the authors. Several factors discussed in the U. S. Congress Office of Technology Assessment report (1989) suggest that the demand elasticity is higher (more elastic) than that for recycled old newspapers:

- the current recycling rate for cullet is about 15 percent, but a cullet charge of 70 to 80 percent is used in some glass-making facilities and a mix of 25 percent cullet is commonplace;
- environmental regulations and aesthetic concerns about sand mining are restricting the extraction of the virgin material;
- "curbside cullet" color separation has been good;
- glass producers have publicly announced a desire to use more cullet; and
- "glassphalt" is potentially a very good market.

The own-price demand elasticity for cullet is subjectively assumed to be higher than that for old newspapers, and the value of -2.0 is assumed.

The projected best-estimate equilibrium price of post-consumer glass following implementation of the materials separation requirement is $27 per ton—about 11 percent below baseline. Other impact estimates are presented in Table 5-2 as well.

5.2.3 Post-Consumer Aluminum Used Beverage Containers

Table 5-3 presents model parameter assumptions and impact estimates in the post-consumer aluminum used beverage container market.

Powell (1990) estimates that 844 thousand tons of aluminum cans were recovered in 1989, an increase of 12.2 percent over 1988. Assuming the same percentage increase from 1989 to 1990, the 1990 baseline estimate is 947 thousand tons—reported in Table 5-3.

Recycling Times (August 28, 1990) shows prices paid by processors for aluminum used beverage containers. Prices during the first two weeks of August 1990 vary from

$440 to $880 per ton, depending on the region of the country. Across regions, $800 looks representative.

A Producer Price Index exists for aluminum scrap. Given a 1982 index of 100.0, the index has been as high as 228.7 (in 1988) and as low as 127.5 (in 1985) in the last five years. The 1990 Producer Price Index for aluminum scrap is 172.8.

Apotheker (1989) reports that the toll end price paid for truckload quantities of bailed aluminum UBCs has ranged from a low of $620 in June of 1985 to a high of about $1,400 in June of 1989 in nominal prices. In 1990 dollars (using the GNP Implicit Price Deflator), these figures translate into a range of about $725 to $1,440. Dealers must pay municipalities less than the toll end price. The article suggests that a "street price" of $540 per ton is consistent with a "toll price" of $840 per ton. Consequently, an estimated range for the "street price" of aluminum used beverage containers of $466 [(540/840) $725] to $926 [(540/840) $1,440] per ton can be derived.

Powell (1990) reports that "American consumers and scrap dealers" received more than $900 million for 844 thousand tons of scrap aluminum cans in 1989. This figure translates into a price of $1,066 per ton in a year when scrap aluminum prices were high.

For this analysis, a range of $500 to $1,000 per ton received by municipalities for recycled aluminum used beverage containers is assumed as a baseline long-run equilibrium price, with a best estimate toward the upper end of the range: $800 per ton.

No known published estimates of the own-price demand elasticity for aluminum used beverage containers exist. But information from the U. S. Congress Office of Technology Assessment (1989), Powell (1990), and the U. S. Department of Labor Bureau of Labor Statistics (June, 1990) suggests that the demand elasticity is high:

- primary aluminum production is much more fuel intensive than aluminum production using recycled aluminum;
- aluminum used beverage containers are easy for aluminum producers to use;
- demand for used beverage containers is strong;
- export demand for aluminum used beverage containers is strong; and
- aluminum scrap prices are fairly stable over time, even in the face of increasing supplies of post-consumer materials.

For these reasons, the elasticity is assumed to be still higher than that for glass cullet. A value of -4.0 is assumed in this analysis.

The projected best-estimate equilibrium price of post-consumer aluminum beverage containers following implementation of the materials separation requirement is $793 per ton—about one percent below baseline. Other impact estimates are presented in Table 5-3 as well.

5.2.4 Post-Consumer Steel Containers

Table 5-4 presents model parameter assumptions and impact projections in the post-consumer steel can market.

Franklin (1990) reports that approximately 400 thousand tons of post-consumer steel containers were recovered for recycling in 1988. The 1988 estimate is adjusted upward to the 1990 estimate of 576 thousand tons based on a report that the recycling rate for steel food and beverage cans increased from 15 percent in 1988 to 21.6 percent in 1989 (Powell, 1990). The 1990 estimate may be conservative because it assumes the recycling rate in 1990 remained at the 1989 level.

Recycling Times (August 28, 1990) shows prices paid by processors for clean steel/tin cans. Prices during the first two weeks of August 1990 vary from $45 to $104 per ton, depending on the region of the country. Across regions, $70 per ton looks representative.

The Producer Price Index for iron and steel scrap gives a 1982 index of 100.0, yet the index has been as high as 177.6 (in 1989) and as low as 112.2 (in 1985) in the last five years. The 1990 Producer Price Index for iron and steel scrap is 167.7.

Prices of delivered iron and steel scrap are reported by the U. S. Bureau of Mines (1990). Since 1985, scrap prices (in 1990 dollars) have ranged from as low as $74.64 (1986) to as high as $104.18 (1988). The 1990 scrap price is $91.61.

The ratio of the representative steel can processor price in 1990 ($70) to the delivered steel scrap price in 1990 ($91.61) is 0.76. Applying this ratio (assuming constancy in recent years) to six-year low and high scrap prices, estimated low and high steel can processor prices in 1990 dollars are $56.73 [0.76 * $74.64] and $79.18 [0.76 * $104.18].

For this analysis, a range of $55 to $80 per ton received by municipalities for recycled steel cans is assumed as a baseline long-run equilibrium price, with a best estimate of $70.

No known estimates of the own-price demand elasticity for post-consumer steel containers exist, but data reported by the U. S. Congress Office of Technology Assessment (1989) and the U. S. Department of Labor Bureau of Labor Statistics (June, 1990) suggest a high elasticity:

- municipal solid waste scrap steel is mostly tin cans, which need to be de-tinned;
- de-tinning companies de-tin cans to recover the tin, and de-tinning capacity is growing;
- electric arc furnace (EAF) steel making facilities are major demanders of steel scrap, and EAF capacity is growing rapidly;
- ferrous scrap export demand is strong; and
- steel scrap prices have been fairly robust over time.

The projected best-estimate equilibrium price of post-consumer steel following implementation of the materials separation requirement is $66 per ton—about 5.6 percent below baseline. Other impact estimates are presented in Table 5-4 as well.

5.2.5 Post-Consumer Plastic Containers

Table 5-5 presents model parameter assumptions and impact projections in the post-consumer plastic containers market.

The 1990 baseline quantity of recycled plastic containers is the most difficult of the secondary materials to estimate. Franklin (1990) estimates that 100 thousand tons of post-consumer plastic containers were recycled in 1988. Market forecasters project a five- to ten-fold growth in this volume in the next five years alone (Basta and Johnson, 1989). A Business Opportunity Report (Schlegel and Fuller, 1989) projects that 550 thousand tons of plastic containers will be recycled in 1991—about a five-fold increase. The 1990 estimate reported in Table 5-5 subjectively assumes that the 1990 baseline recycled quantity is twice the 1988 estimate. The direction and magnitude of the bias is difficult to assess.

Recycling Times (August 28, 1990) shows prices paid to and by (a mixture) processors for baled, color-sorted PET and HDPE. Prices during the first two weeks of

August 1990 vary from $0 to $200 per ton, depending on the region of the country. Across regions, $120 per ton looks representative.

Other plastic scrap data are very scarce because this is such a new market, even relative to other secondary materials markets.

Recycling Today (April 15, 1990) reports that "the demand for plastic household bottles and jugs is strong and growing" and that "companies are building new plants to reclaim plastics and demanding more materials from sources."

For this analysis, because there is so little historical data to rely on, a relatively wide range of $50 to $250 per ton received by municipalities for recycled plastic bottles and jugs is assumed as a baseline long-run equilibrium price, and today's prevailing price of $120 is the best estimate because it is near the middle of the range.

Estimates of the own-price demand elasticity for recycled plastic containers do not exist. The U. S. Congress Office of Technology Assessment (1989) reports that "lack of collection is a major barrier to the recycling of plastics" and that "market studies for PET and HDPE (the two main constituents of consumer plastics) show enormous potential."

Recycling Today (April 15, 1990) reports that demand for recycled plastics is outpacing supply and that new products manufactured from recycled plastics are being developed. The source also reports that companies are building new plastic reclamation plants and that Wellman, the largest recycler of PET in the U.S., has a "tremendous appetite" for more post-consumer plastic.

For these reasons, the demand elasticity is assumed to be the same as that for steel and aluminum containers, -4.0.

The projected best-estimate equilibrium price of post-consumer plastic following implementation of the materials separation requirement is $86 per ton—about 28 percent below baseline. Other impact estimates are presented in Table 5-5 as well.

TABLE 5-1. MSR IMPACTS ESTIMATES: POST-CONSUMER NEWSPAPER MARKET

Parameters:	Baseline Quantity (10^3 tons):	5,371
	Baseline Price ($/ton):	$5 to $42 ($10 best estimate)
	Elasticity of Demand:	-0.71
	Elasticity of Supply:	1.6
	Net Diversion (10^3 tons):	805 (15% of baseline)
Results:	Post-MSR Price ($/ton):	$4.68 to $39.27 ($9.35 best estimate)
	Price Change:	(-6.5%)
	Post-MSR Quantity (10^3 tons):	5,618
	Quantity Change (10^3 tons):	+247 (+4.6%)

TABLE 5-2. MSR IMPACTS ESTIMATES: POST-CONSUMER GLASS MARKET

Parameters:	Baseline Quantity (10^3 tons):	1,800
	Baseline Price ($/ton):	$20 to $80 ($30 best estimate)
	Elasticity of Demand:	-2.0
	Elasticity of Supply:	1.6
	Net Diversion (10^3 tons):	714 (40% of baseline)
Results:	Post-MSR Price ($/ton):	$18 to $71 ($27 best estimate)
	Price Change:	(-11%)
	Post-MSR Quantity (10^3 tons):	2,197
	Quantity Change (10^3 tons):	+397 (+22)

TABLE 5-3. MSR IMPACTS ESTIMATES: POST-CONSUMER ALUMINUM MARKET

Parameters:	Baseline Quantity (10^3 tons):	947
	Baseline Price ($/ton):	$500 to $1,000 ($800 best estimate)
	Elasticity of Demand:	-4.0
	Elasticity of Supply:	1.6
	Net Diversion (10^3 tons):	47 (5% of baseline)
Results:	Post-MSR Price ($/ton):	$495 to $991 ($793 best estimate)
	Price Change:	(-0.9%)
	Post-MSR Quantity (10^3 tons):	981
	Quantity Change (10^3 tons):	+34 (+3.5%)

TABLE 5-4. MSR IMPACTS ESTIMATES: POST-CONSUMER STEEL MARKET

Parameters:	Baseline Quantity (10^3 tons):	576
	Baseline Price ($/ton):	$55 to $80 ($70 best estimate)
	Elasticity of Demand:	-4.0
	Elasticity of Supply:	1.6
	Net Diversion (10^3 tons):	180 (31% of baseline)
Results:	Post-MSR Price ($/ton):	$52 to $76 ($66 best estimate)
	Price Change:	(-5.6%)
	Post-MSR Quantity (10^3 tons):	704
	Quantity Change (10^3 tons):	+128 (+22%)

TABLE 5-5. MSR IMPACTS ESTIMATES: POST-CONSUMER PLASTIC MARKET

Parameters:	Baseline Quantity (10^3 tons):	200
	Baseline Price ($/ton):	$50 to $250 ($120 best estimate)
	Elasticity of Demand:	-4.0
	Elasticity of Supply:	1.6
	Net Diversion (10^3 tons):	311 (156% of baseline)
Results:	Post-MSR Price ($/ton):	$36 to $180 ($86 best estimate)
	Price Change:	(-28%)
	Post-MSR Quantity (10^3 tons):	422
	Quantity Change (10^3 tons):	+222 (+111%)

CHAPTER 6
NATIONAL MATERIALS SEPARATION COSTS AND TOTAL DIVERSION

The net cost of the materials separation requirement equals the sum of capital costs and operating and maintenance costs of separation (recycling in this study) minus the credit for downsizing planned municipal waste combustors, avoided landfill costs, avoided garbage collection costs, and revenues from the sale of diverted materials. Two estimates of net costs are presented (see Table 6-1).

The net cost of the materials separation requirement may be as low as -86 million dollars (annualized), i.e., a savings, or as high as 367 million dollars (annualized). Obviously the estimates describe a range, but neither estimate was made with the intention of finding an extreme.

Chapters 3 and 5 describe in detail the differences in assumptions underlying the two estimates of net cost, but a summary will be helpful here. Four components of net cost differ: total separation, avoided landfilling, avoided garbage collection, and revenue.

1) The category of cost labeled "Total Separation" refers to the annualized capital and operating costs of collection systems, materials recovery facilities, recycling transfer facilities, and centralized composting facilities. This category also includes the cost of administration. The difference in "Total Separation" cost is due to the difference in administrative effort: the higher cost reflects the addition of staff whose purpose is to demonstrate compliance with the New Source Performance Standards and Emission Guidelines.

2) The difference in the two estimates of avoided landfill cost is due to different estimates of the unit cost of landfilling ($45.65/Mg or $22.31/Mg). The greater unit cost is the result of averaging two different weighted average costs of landfilling (one weighted by daily throughput capacity, the other weighted by landfill type). The lesser unit cost ($22.31.Mg) is the result of statistically analyzing the relationship between landfill size and cost.

3) The avoided garbage collection cost is either $269 million or $86 million. The greater estimate results from modeling garbage collection with and without recycling in high population/high density, medium population/medium density, and very small population/low density communities. The lesser estimate results from applying the statistical analysis of garbage collection costs conducted by Savas and Stevens (1978).

4) The last source of difference in net cost is the revenue obtained from the sale of old newspapers and steel, aluminum, glass, and plastic containers (see Tables 6-2 and 6-3). As discussed in Chapter 5, the new price of a secondary material depends on the baseline price (among other things). The greater estimate of total revenue reflects the assumption of greater baseline prices, hence, greater post-separation prices.

Appendix E presents the results of several sensitivity analyses. Table E-6 identifies the net cost of materials separation when all MWCs larger than 35 MgPD capacity are included (the results presented in this chapter reflect the exclusion of MWCs in certain areas of the country). Table E-7 reflects the exclusion of MWCs below 100 MgPD capacity. Table E-8 identifies the net cost of materials separation under the assumption that all model programs include a composting program in which householders set out bagged yard waste and leaves, the bags are collected by a paid collection crew, and the community operates a centralized composting facility (the results presented in this chapter reflect a mix of backyard and centralized composting programs).

TABLE 6-1. MATERIALS SEPARATION COSTS, AVOIDED COSTS, AND REVENUES FOR MWCS AT LEAST 35 MEGAGRAMS PER DAY CAPACITY[a]

	Estimate One	Estimate Two
(annualized millions of dollars)		
Total Separation	$565	$657
Downsizing	($90)	($90)
Avoided Landfilling	($161)	($82)
Avoided Garbage Collection	($131)	($32)
Materials Separation Revenue	($269)	($86)
Total	($86)	$367
(annualized $ per Mg)		
$ Per Mg Collected	($15)	$65
$ Per Mg Combusted	($3)	$11

[a] There are 280 existing and planned MWCs. Of these, 66 are in CT, DC, FL, LA, MN, NC, NJ, OH, VA, and WA, and they are excluded from the analysis. Of the remaining 214, 21 are below the size cutoff, leaving 193 in the analysis.

TABLE 6-2. NET QUANTITIES DIVERTED, PRICES, AND REVENUES FOR ESTIMATE ONE

	Diverted Materials		
	Net Diversion (Mg/Yr)	High Price ($/Mg)	Revenues ($)
Newspaper	1,090,404	43.30	47,214,486
Glass	744,606	78.28	58,287,739
Aluminum	75,980	1,092.58	83,014,425
Ferrous containers	189,950	83.79	15,915,948
Plastic	323,980	198.45	64,293,900
Total			$268,726,498

TABLE 6-3. NET QUANTITIES DIVERTED, PRICES, AND REVENUES FOR ESTIMATE TWO

	Diverted Materials		
	Net Diversion (Mg/Yr)	Low Price ($/Mg)	Revenues ($)
Newspaper	1,090,404	5.16	5,626,484
Glass	744,606	19.85	14,780,424
Aluminum	75,980	545.74	41,465,423
Ferrous containers	189,950	57.33	10,889,859
Plastic	323,980	39.69	12,858,780
Total			$85,620,971

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APPENDIX A: LEGISLATION AND PROCUREMENT GUIDELINES

This appendix highlights state and national recycling legislation and procurement guidelines that have been developed to stimulate demand for recyclables and avoid market place gluts.

State legislatures have recently passed or introduced numerous pieces of legislation concerning recycling. To help set the direction for local solid waste management, some states are developing comprehensive waste management strategies. In addition, some states are addressing local conditions and needs by sponsoring a range of complementary programs, including funding pilot demonstration projects, awarding technical assistance grants, and providing economic incentives.

At the regional level, states are grouping themselves into economic regions by creating interstate compacts. For example, several northeastern states have joined together to promote recycling. The June 1988 issue of *Waste Age* reports that

> The coalition of Northeastern Governors (CONEG) is advocating a coordinated, comprehensive, solid waste management policy incorporating source reduction and recycling, refuse-to-energy, and landfilling (Curlee, 1989, p. 8).

By acting as an economic region, states in compacts can tackle issues such as developing long-term uses for the materials recovered from the solid waste stream and promoting consumer acceptance of products made from such materials. Working together as a region changes the nature of the relationship between states from market competition (where each state seeks to unload its own recovered materials) to one of cooperation (where states work together to develop a market for all the materials generated in the region). Compacts also enable states to pool resources for research and development projects and joint ventures (Kovacs, 1988).

The federal government's role in promoting recycling includes establishing procurement guidelines for purchasing items containing recovered materials, providing technical assistance to states, funding research and development projects on the uses of recovered materials, and supporting recycling and use of recovered materials with federal tax incentive policies.

A.1 STATE SUMMARY

Recent nationwide surveys indicate that fifteen states, including the District of Columbia, have enacted mandatory comprehensive recycling laws that set minimum requirements for local solid waste management plans (see Table A-1). Several statewide laws set goals for recycling at 25 percent (although the goals range from 10 percent to 50 percent). For example, California and Washington have mandated a 50 percent recycling goal, while Delaware and Wisconsin have a 10 percent goal. Some state recycling laws have strong economic measures that take effect if the goals are not met (Curlee, 1989).

Some states mandate local government and citizen participation in collection efforts. For example, New Jersey, Rhode Island, Washington, Connecticut, New York, the District of Columbia, and Pennsylvania mandate that citizens and businesses source-separate "designated" recyclables. In Maine, source separation requirements apply only to offices (NSWMA, 1989). New Jersey's 1987 "Mandatory Recycling Act" requires that

- local governments design their own programs,
- county recycling plans identify how recyclables are to be processed and marketed, and
- households separate at least three materials (to be selected by the local governments).

The Act gave municipalities until 1989 to achieve a recovery rate of 25 percent. The state provided $8 million in start-up aid to municipalities (Curlee, 1989).

Some states require local jurisdictions to offer or provide recycling as an option to households. Oregon, one of the first states to promote recycling, enacted an "Opportunity to Recycle" Law in 1983 that requires municipalities with populations over 4,000 to provide recycling drop-off centers and offer curbside collection of recyclables at least once per month. Household participation is voluntary (Curlee, 1989).

Minnesota, Oregon, Ohio, North Carolina, Washington, Wisconsin, and Hawaii mandate that local governments provide curbside collection service in certain communities (NSWMA, 1989 and Glenn, 1990). Meeting mandatory recycling goals is often linked to permitting new disposal capacity and financing solid waste management programs. For example, Maryland will not issue a permit to install or alter an incinerator unless the host county has submitted a state-approved recycling plan (Snow, 1989).

Florida enacted solid waste legislation in 1988 designed to change people's solid waste management habits, provide incentives for recycling, protect the environment, stimulate recycling markets, and conserve landfill space and waste-to-energy capacity. During fiscal year 1988-89, Florida appropriated $28.7 million for local recycling

TABLE A-1. STATE COMPREHENSIVE RECYCLING LAWS

State	Recycling Goal[a]	Mandated Goal	Mandatory Source Separation	Mandatory Municipal Recycling Ordinance	Mandatory Local Recycling Planning
California	50% by 2000[b]	X			X
Connecticut	25% by 1991	X	X		
Delaware	10% by 1994				
District of Columbia	35% by 1994	X	X	X	
Florida	30% by 1995	X			X
Illinois	25% [c] by 2000	X			X[d]
Indiana	25% by 1992				
Iowa	50% by 2000				X
Louisiana	25% by 1992	X			
Maine	50% by 1994		X[e]		
Maryland	20% by 1994 [f]	X			X
Massachusetts	38% by 2000				
Michigan	20-30% by 2005				X
Minnesota	25% by 1993	X			X
Missouri	35% by 2000				
New Jersey	25%by 1992	X	X	X	X
New York	40% by 1997		X	X	
North Carolina	25% by 1993	X			X
Ohio	25% by 1994	X			
Pennsylvania	25% by 1997	X	X	X	
Rhode Island	maximum by 1993 possible[g]	X	X	X	
Vermont	40% by 2000	X			X
Virginia	25 % by 1995	X			X
Washington	50% by 1995	X	X		
West Virginia	30% by 2000				
Wisconsin	10% by 2000				

[a]Includes leaf or yard waste composting.
[b]May include 10 percent waste transformation.
[c]This goal applies to counties with populations greater than 100,000.
[d]9/91 for counties over 100,000 population and cities over 1,000,000.
3/95 for counties with less than 100,000 population.
[e]Source separation requirements only apply to offices.
[f]Twenty percent recycling is the optimal goal. Counties with populations greater than 150,000 must recycle at least 15 percent of their waste. Counties with populations under 150,000 must recycle at least 5 percent of their waste.
[g] Municipalities must achieve at least 15 percent recycling.
Note: This chart depicts requirements of both new and revised comprehensive recycling laws; the date of the most recent law is given. Recycling plans may be a component of state or municipal solid waste management plans or separate requirements. Only final recycling goals are listed; states often include source reduction and composting in this percentage.
Source: NSWMA, 1989 and Glenn, 1990.

programs and almost $1.3 million for research. Under the new law, each county was to initiate a recycling program by July 1, 1989 (Kirkpatric, 1988). County recycling programs can be implemented either at a central location or through curbside collection programs.

As shown in Table A-1, eleven states require local jurisdictions to include recycling in solid waste management plans. In some cases, mandatory implementation of the plan is not required.

Table A-2 describes other types of initiatives, such as redemption programs, financial incentives, laws favoring procurement, and technical assistance, that states are pursuing.

Redemption Programs

Current mandatory bottle deposit programs are effective in ensuring that items are returned to manufacturers for reuse or recycling. Roth reports that bottle reclamation in states with bottle deposit laws averages 90 percent or better. Deposit programs typically require the consumer to pay a five-cent deposit on beverage containers, which can be redeemed when the bottles are returned to the retailer. When states began bottle-deposit programs in the 1970's, the intent was to encourage refillable bottles; now, however, manufactures opt for recycling.

In addition to beverage containers, some jurisdictions have recently established redemption programs for tires, automobile batteries, and motor oil. For example, Minnesota charges a $1 fee on the sale of new tires, which helps fund a tire-recycling facility (Andress, 1989). Currently, five states have legislation requiring retailers to accept old batteries at the time of a sale. Three states (Minnesota, Washington, and Rhode Island) charge a fee if an old battery isn't returned at the time of purchase (Glenn, 1990).

Florida's advance disposal fee is a variation of the deposit idea. Under this law, manufacturers are assessed one cent per container (i.e., glass, plastic, plastic-coated paper, aluminum, and other metals) on containers that are not recycled at a sustained rate of 50 percent by October 1, 1992. The fee increases to 2 cents in 1995 if the target is not met by October 1, 1995 (Andress, 1989).

TABLE A-2. SELECTED CHARACTERISTICS OF STATE RECYCLING PROGRAMS

State	Deposit or Redemption Requirements	Disposal Restrictions	Package/Product Tax or Fee	Education/Promotion	Regional Recycling Facilities	Technical Assistance	Tax Incentives	Procurement	Research	Other
Arkansas									X	State is sponsoring a recycling feasibility study.
California	X		X	X				X		No landfill permit until community has a plan for 20% recycling.
Colorado								X		
Connecticut	X	X		X	X	X		X	X	Packaging studies required.
Delaware	X									State operates RDF/ mechanical separation facility.
Dist. of Columbia								X		Source separation to be phased in by 1990.
Florida	X	X	X	X		X	X	X	X	Advance disposal fee on all containers. Special fees on tires and newsprint.
Hawaii		X						X	X	Waste-stream study under way.
Illinois	X	X	X	X		X		X	X	Disposal surcharge supports Solid Waste Management Fund.
Indiana							X			
Iowa	X	X		X		X		X		Disposal surcharge funds landfill alternative grants.
Louisiana			X					X		
Maine	X							X		12/88 Report to legislature outlines aggressive waste reduction/recycling program.

continued

TABLE A-2. SELECTED CHARACTERISTICS OF STATE RECYCLING PROGRAMS (CONTINUED)

State	Deposit or Redemption Requirements	Disposal Restrictions	Package/ Product Tax or Fee	Education/ Promotion	Regional Recycling Facilities	Technical Assistance	Tax Incentives	Procurement	Research	Other
Maryland						X		X		After 1990, no incinerator permits until recycling plans are approved.
Massachusetts	X			X	X	X		X	X	State grant for experimental mixed plastics facility.
Michigan	X			X		X		X	X	State sponsoring 10 "model" recycling projects.
Minnesota	X	X		X		X		X	X	Counties must address recycling in solid waste plans to receive new disposal facility permits. State has tire recycling program.
Missouri								X		Solid waste plans required for large counties. State seeking to expand recycling clearinghouse role.
Nebraska						X				Tax on consumer items used for grants for anti-litter and recycling projects.
New Hampshire								X		Counties required to prepare solid waste plans that address recycling.
New Jersey		X		X		X	X	X	X	Recycling Fund supported by disposal surcharge.
New York	X			X		X		X	X	Planning units to develop solid waste plans that include waste reduction.

continued

TABLE A-2. SELECTED CHARACTERISTICS OF STATE RECYCLING PROGRAMS (CONTINUED)

State	Deposit or Redemption Requirements	Disposal Restrictions	Package/ Product Tax or Fee	Education/ Promotion	Regional Recycling Facilities	Technical Assistance	Tax Incentives	Procurement	Research	Other
North Carolina		X	X				X	X		State offers technical assistance for waste reduction.
Ohio		X		X		X		X		Counties must develop waste management plans. Disposal surcharge funds program.
Oklahoma			X					X		
Oregon	X	X	X	X			X	X		State has lower freight rates for recyclables.
Pennsylvania	X	X		X		X		X	X	Recycling program funded by disposal surcharge.
Rhode Island	X		X	X	X	X		X	X	Deposit on batteries. Commercial sector must source-separate wastes as of 1/89.
Texas								X		Local solid waste plans must include recycling, but plans are not required.
Vermont	X			X		X		X	X	Solid Waste Fund funded by franchise tax on landfill owners.
Virginia			X					X		Local governments allowed to mandate source separation.

continued

TABLE A-2. SELECTED CHARACTERISTICS OF STATE RECYCLING PROGRAMS (CONTINUED)

State	Deposit or Redemption Requirements	Disposal Restrictions	Package/ Product Tax or Fee	Education/ Promotion	Regional Recycling Facilities	Technical Assistance	Tax Incentives	Procurement	Research	Other
Washington	X	X	X	X		X		X	X	State to complete a study of best waste management practices for entire waste stream. A tire tax funds tire recycling program.
West Virginia									X	Disposal surcharge used to fund recycling study and general waste management activities.
Wisconsin		X	X				X	X		Cities and landfill owners must provide for drop-off centers.
Wyoming	X	X								

Source: Andress, 1989 and Glenn, 1990.

Financial Incentives

Three main types of tax incentives are available for recycling activities: investment tax credits, sales tax exemptions, and property tax exemptions (U. S. Congress, OTA, 1989).

Six states offer tax incentives to promote recycling activities. For example, Oregon gives income tax credits for the purchase of recycling equipment and facilities. New Jersey gives investment credits of 50 percent for buying recycling equipment. Property tax exemptions are offered in Indiana for buildings, equipment, and land used for recycling operations. Wisconsin offers tax exemptions for equipment and facilities as well as business property tax exemptions for recycling equipment. North Carolina allows industrial and corporate tax credits and exemptions for recycling equipment and facilities (Curlee, 1989).

Low-interest loans and loan guarantees for investments in recycling equipment and operations can lower companies' financing costs. For example, New Jersey's low-interest loan program provided about $3 million to 12 businesses in its first three years (Andress, 1989).

Procurement Guidelines

To increase demand for recycled products, some states are enacting laws that "favor" procurement of recycled products. These state laws range from suggestions that state agencies should purchase products that contain recycled materials to price preferences for state purchases of recycled products (Andress, 1989). For example, Oregon allows its state departments to pay up to 5 percent more for recycled products that contain either 50 percent industrial waste or 25 percent postconsumer waste, as compared to products made from virgin materials. Vermont has set goals for purchasing 25 and 40 percent recycled goods by 1990 and 1993, respectively. The procurement program in New York provides a 10 percent price preference and requires that products have a recycled content of at least 40 percent. California's law provides a 5 percent price preference and requires a recycled content of 50 percent, including 10 percent post-consumer waste (Curlee, 1989). In Illinois, The Solid Waste Management Act of 1986 requires the total volume of paper and paper products purchased by the state's central purchasing agency to contain at least 25 percent recycled materials by 1992 and at least 40 percent by 1996 (Solid Waste Report, 1990e).

State paper procurement policies have not had much collective effect on the markets because the definition of "recycled content" varies state by state. For example, while New York requires a minimum of 40-percent recycled fiber content in its paper, Maryland specifies an 80-percent recycled fiber content. The lack of uniformity among states makes manufacturers unwilling to provide adequate supplies of products and, therefore, contributes to increased prices for recycled products. This absence of common definitions and specifications for recycled products underscores the importance of federal guidelines. In fact, since the federal government issued guidelines for recycled paper in June 1988, ten northeast states have agreed to adopt them for state purchases (Andress, 1989).

Technical Assistance

Some states assist communities by sponsoring pilot projects and providing technical assistance. This help can answer questions and overcome skepticism, especially in communities that have little or no recycling experience (Andress, 1989).

Here are some examples of state technical assistance programs:

- Virginia's General Assembly set recycling goals during its 1989 session. To facilitate implementation of local or regional recycling programs, Virginia's Department of Waste Management has made $100,000 in grants available to local governments for demonstration programs. Virginia expects all its local governments to gain useful information from the demonstration programs (Commonwealth of Virginia, Department of Waste Management, 1989).

- Pennsylvania also recently awarded $577,948 in grants and loans from the newly created Environmental Technology Fund. Some of the money will be used to study the use of recycled plastic polymers, develop a computer bulletin board to serve as a communications network for the recycling industry, and study the chemistry of a de-inking and defibering process for wastewater (*Solid Waste Report*, 1990b).

- Missouri will award $1.2 million to cities, counties, local governments, and non-profit groups to establish aluminum, glass, and paper recycling programs that emphasize collection, marketing, and composting (*Solid Waste Report*, 1990d).

- Under Public Act 86-256, Illinois is providing $1.25 million in recycling grants to cities with populations over 20,000. Grant recipients will be required to implement pilot recycling projects that demonstrate the economic feasibility and environmental benefits of a combination of recycling methods (i.e., curbside collection, drop-off and buy-back centers) (*Solid Waste Report*, 1990c).

- Minnesota will award Martin County and Wright County grants of $2 million each for planned municipal solid waste composting facilities (*Solid Waste Report*, 1990b).

A.2 NATIONAL SUMMARY

The federal government is using a variety of initiatives to supplement and support states in solving their solid waste problems, to expand or increase market development, to coordinate research and technology transfer, to award research and demonstration grants, and to set minimum requirements for state programs.

Pending Legislation

Current pending federal legislation is aimed at stimulating recycling by requiring government agencies to use recycled paper, compost for highway planting, and tire fragments for rubberized asphalt in paving.

Financial Incentives

Industrial development bond (IDBs) are an important federal economic development tool for state and local governments. State and local agencies issue the bonds, which pay interest that is exempt from federal taxation. Expanding the use of IDBs to include a range of recycling projects would give states more low-cost ways to support recycling markets (Andress, 1989).

Procurement Guidelines

Section 6002 of the 1976 Resource Conservation and Recovery Act requires EPA to establish guidelines for federal agencies to buy recycled products. EPA is responding by establishing procurement guidelines for an expanded product list. This list includes such products as recycled paper, re-refined oil, remanufactured tires, and building insulation made from recycled materials (Keller, 1988).

Federal government purchases have both a direct and an indirect impact on the marketplace. Government purchases are of sufficient size to directly influence industry to invest in research and equipment for using recycled materials. (Recent studies indicate that federal government purchases represent about 7 percent of the Gross National Product.) Federal government purchases can have an indirect effect on the market because private agencies and states frequently adopt the purchasing standards and specifications set by the federal government. In addition, private agencies and states can purchase recycled paper from the same vendors as the government (Keller, 1988).

Technical Assistance

Federal support is important in such areas as funding states and universities to develop new technologies, funding demonstration projects, funding research into manufacturing processes to identify specific products or components of products that create problems for recycling, creating a national clearing house of information on successful recycling activities, and determining what products the government can purchase that are made from recovered materials rather than from virgin sources (Andress, 1989).

APPENDIX B
PAPER AND PAPERBOARD INDUSTRY PROFILE

The flow of secondary materials to the paper and paperboard industry occurs because waste paper, after treatment, is an accepted substitute for raw material (pulp) consisting of virgin fiber. Newsprint, for example, may be made entirely of pulp produced from fiber that most recently was standing timber; alternatively the direct source of the pulp may be old newspapers recovered from a community recycling program. A dual perspective is necessary to completely discuss statistics on the flow of secondary materials. When the emphasis is on an intermediate or final product, for example, kraft paperboard, the quantities of different waste paper grades (and virgin material), which are inputs to the manufacture of that product are described. Conversely, when the emphasis is on a grade of waste paper, the quantities of different intermediate or final products whose manufacture uses that grade are described. The organization of this appendix corresponds to these two different ways of portraying material flows: by intermediate or final product and by grade of waste paper.

Following the presentation of past and present statistics on secondary materials and the production of paper and paperboard, the appendix briefly summarizes recent governmental initiatives to influence the use of secondary materials, including waste paper. Although not exhaustive, it conveys the range of market interventions that could substantially affect the paper and paperboard industry, making it a very different industry in the future.

B.1 RAW MATERIALS

Table B-1 provides a complete listing of the primary products (intermediate and final) that paper, paperboard, and construction paper generate. Figure B-1 shows the general flow of paper and paperboard products from the manufacture of intermediate and final products to the disposal of wastepaper and paperboard through landfilling and incinerating or through recycling.

The demand for raw materials, hence the demand for virgin or secondary pulp, originates in the input selections chosen by the operators of paper and paperboard mills. Almost all paper and paperboard mills that consume wood pulp use captive, virgin raw materials. In 1968, 89.4 percent of all wood pulp consumed in domestic paper mills was produced from captive, virgin raw materials. Paper or paperboard mills tied directly to pulp mills at the same location consumed most of this captively produced wood pulp. Conversely, almost all wastepaper is

TABLE B-1. PRINCIPAL PRODUCT CATEGORIES FOR PAPER

Category	Product Group	Principal Products
Paper	Newsprint	Newspapers
	Printing and writing papers	Books, magazines, commercial printing, office papers, forms, bond, cotton fiber, file folders, computer paper, envelopes, etc.
	Packaging and industrial	Sacks, bags, wrapping paper, shipping sacks, industrial papers, etc.
	Tissue	Toilet, facial, napkins, toweling, packaging, etc.
Paperboard	Containerboard	Corrugated boxes
	Boxboard and other paperboard	Cartons, plates, cups, tube, can and drum, milk cartons, pad backs, etc.
Construction	Construction	Insulating board, pressed board, etc.

Source: Franklin Associates, 1988.

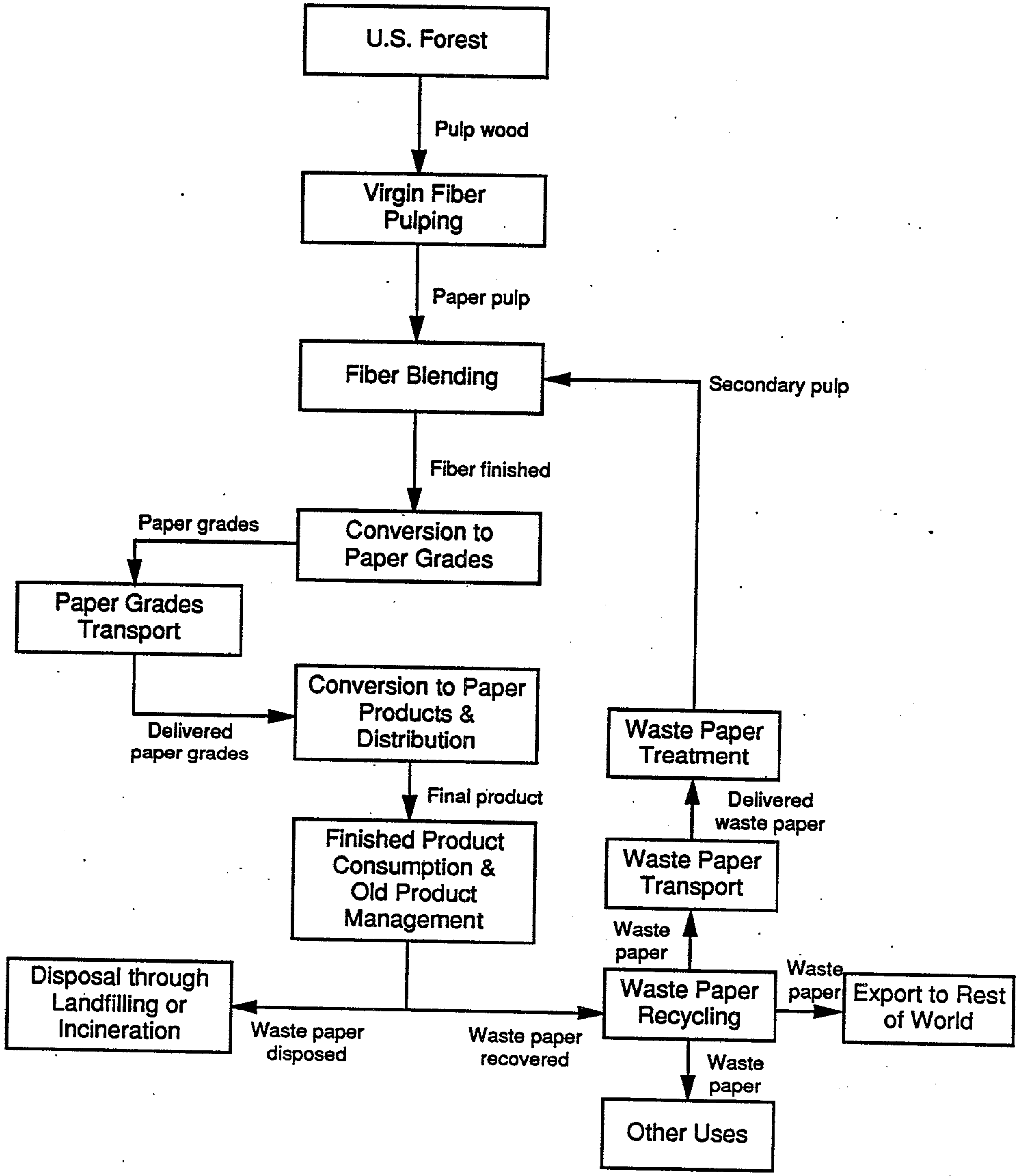

Figure B-1. Flow of Paper and Paperboard Production

consumed by independent mill operations that depend on purchased wastepaper for raw materials. This is true even for those organizations with wastepaper dealer subsidiaries (Franklin Associates, 1989).

According to the American Paper Institute (API), the U.S. has approximately 600 pulp, paper, paperboard, and building products mills. Of these 600 mills, 200 almost exclusively use wastepaper for their fibrous raw material, and 300 use some wastepaper, leaving 100 that use only virgin raw materials.

Paper mills that rely on virgin wood pulp are concentrated in the South, Northeast, North Central states, and the West Coast, where commercial timberlands are located. Mills that use paper stock are located predominantly in the East, North Central, and Middle Atlantic states, close to population centers that generate paper stock and consume mill outputs (Franklin Associates, 1989).

Over the next three years, the demand for recycled fiber is expected to grow at two times the rate of demand for virgin fiber. One Canadian mill is currently producing 340,000 tons of recycled newsprint a year with 55 percent recycled fiber content. Another recycled newsprint mill will open late in 1990, and two or three other producers plan to start making recycled newsprint in 1991. Three new newsprint recycling mills are planned in the U.S. (API)

B.2 PRODUCTS CONTAINING RECYCLED POSTCONSUMER MATERIALS

Wastepaper and paperboard are subdivided into five main categories or grades:

- old newspapers,
- old corrugated containers,
- mixed paper,
- high-grade deinking paper, and
- pulp substitutes.

Although the Paper Stock Institute of America lists over 49 grades of wastepaper and 31 other specialty grades, *recyclable* grades fall into these five divisions (API).

The first four categories are composed at least partially of postconsumer wastepaper—products that have served the purpose they were manufactured for and have been recycled or source-separated (API). Old newspaper (ONP) consists primarily of newspapers discarded by households, although unsold newspapers and publication scrap[1] are also included in this category. Old corrugated containers (OCC) consist of both used corrugated boxes, usually generated by the commercial sector, and new corrugated cuttings from converter plants.[2] OCC is used for manufacturing recycled paperboard, although it has secondary uses in the production of unbleached kraft paperboard and semichemical paperboard. Mixed paper, or unsorted wastepaper, is the lowest grade of wastepaper; it is predominantly used to produce recycled paperboard and construction paper and board. High-grade deinking papers consist of sorted, high-quality office wastepaper and printed scrap from printing and converting plants. This grade is primarily used to make tissue paper but is also used to make fine printing and writing papers.

In contrast to the four categories of wastepaper and paperboard described above, the final category, pulp substitutes, is not postconsumer scrap. Pulp substitutes consist of scrap from printing and converting plants and mills, and neither manufacturing nor converting scrap are categorized as postconsumer waste. Because of their source, pulp substitutes are the highest quality wastepaper. These can be used as direct substitutes for wood pulp. Pulp substitutes are used primarily to manufacture fine printing and writing papers, recycled paperboard, and tissue papers (Franklin Associates, Ltd., 1989).

Table B-2 illustrates two possible methods of presenting data on the use of recycled wastepaper in the manufacture of specific end uses: (1) by wastepaper grade recycled, and (2) by secondary product manufactured from the recycled wastepaper. Reading Table B-2 by column (method 1), the upper numbers describe the amount of each type of wastepaper used in the manufacture of a certain product, while the lower figures are the percentage of raw materials each waste grade represents in the manufacture of that product. Reading Table B-2 by row (method 2), the numbers represent the amounts of a specified waste grade that are used in the manufacture of different secondary products and sum to the total amount of wastepaper of each grade recycled in the U.S.

Reading Table B-2 by column demonstrates the relative importance of the recycled materials to the manufacture of a specific good. For example, in 1987, 5.3 million tons of tissue products were produced. The tissue production used 2.2 million tons of secondary fiber, giving a

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[1] Publication scrap is pressroom scrap generated in producing newsprint.

[2] Converter plants produce finished paper products, such as envelopes, bags, cartons, and plates, from paper and paperboard grades. These paper and paperboard grades can be made from either recyclable waste paper or wood pulp (Franklin Associates, Ltd. 1972).

TABLE B-2. SECONDARY MATERIALS MATRIX FOR WASTE PAPER SHOWING THE DIFFERENT GRADES AND THE PRODUCTS THEY MAKE

Waste Paper Grade	Product[a] News-print	Fine Printing and Writing	Tissue	Kraft and Packaging Paper	Un-bleached Kraft Paper-board	Semi-chemical Paper-board	Bleached Paper-board	Recycled Paper-board	Construction Paper and Board	Net Exports	Total Waste Paper Recycled	Primary Product Generated (Recycling Rate)
Old Newspaper[b]	1.386 100.00%	0.000 0.00%	0.197 8.77%	0.000 0.00%	0.009 0.50%	0.000 0.00%	0.000 0.00%	1.274 13.97%	0.277 32.10%	0.840 19.56%	3.983 32.00%	13.707 29.058%
Old corrugated containers[b]	0.000 0.00%	0.012 0.91%	0.209 9.31%	0.069 15.33%	1.755 97.12%	1.645 100.00%	0.000 0.00%	5.258 57.65%	0.232 26.88%	1.922 44.75%	11.086 48.10%	23.028 48.14%
Mixed[b]	0.000 0.00%	0.000 0.00%	0.063 2.80%	0.000 0.00%	0.000 0.00%	0.000 0.00%	0.000 0.00%	1.641 17.99%	0.352 40.79%	0.707 16.46%	2.763	__[c]
High-grade deinking[b]	0.000 0.00%	0.336 25.49%	1.051 46.79%	0.007 1.56%	0.052 2.88%	0.000 0.00%	0.000 0.00%	0.116 1.27%	0.002 0.23%	0.526 12.25%	2.072	20.778 9.97%
Pulp Substitutes	0.000 0.00%	0.970 73.60%	0.726 32.32%	0.374 83.11%	0.000 0.00%	0.000 0.00%	0.000 0.00%	0.832 9.12%	0.000 0.00%	0.300 6.98%	3.202	__[c]
Category Total	1.386	1.318	2.246	0.450	1.807	1.645	0.000	9.121	0.863	4.295	23.76	
Domestic Production	5.843	20.778	5.301	5.100	18.898	5.600	4.300	8.508	1.200			
Secondary materials utiliization rate (%)	23.72%	6.34%	42.37%	8.82%	9.56%	29.38%	0.00%	100.00%	71.92%			

[a]Top number is the quantity of product in million tons per year. Bottom number is the percentage of raw materials that the waste paper grade represents in the manufacture of that product.
[b]Includes unsold newspapers, cuttings from converter plants, and other pre-consumer wastes.
[c]No statistics available.
Sources: Franklin Associates, Ltd., 1988, 1989.

secondary materials utilization rate of 42 percent. High-grade deinking and pulp substitutes accounted for 79 percent of the secondary fiber used in tissue manufacture, with the remainder coming from postconsumer waste and lower grades of wastepaper, including 197,000 tons of old newsprint.

Reading Table B-2 by row gives the amount of primary fiber that generated the wastepaper, the amount of wastepaper recovered, the amount of secondary fiber used in the production of other goods, and the net quantity exported. For example, 11.1 million tons of old corrugated containers (OCC) were recovered in 1987. Of that, 290,000 tons were recycled into paper products, 1.8 million tons into unbleached kraft paperboard, 1.6 million tons into semichemical paperboard, 5.3 million tons into recycled paperboard, 232,000 tons into construction paper and paperboard; 1.9 million tons were exported.

This latter method of reading Table B-2 by row focuses on the amount of each type of wastepaper recycled. Thus its focus is on the generation of secondary material rather than on utilization, which is the focus of the first method (reading by column). Each approach is useful for determining the secondary materials markets most likely to use the postconsumer paper generated as a result of the materials separation requirements. For example, Table B-2 shows that a relatively small amount of OCC (one row in the matrix) is used in the manufacture of fine printing and writing papers, newsprint, tissue, draft packaging paper, and construction paper and board (several columns in the matrix); however, 48 percent of OCC is recycled overall. Mandatory separation of OCC from other waste may increase recycling of OCC, but current trends show that industries manufacturing fine printing and writing papers, newsprint, kraft and packing paper, and construction paper and board probably will not increase their use of recycled OCC.

Table B-2 illustrates that the use of wastepaper and paperboard varies greatly by grade. Certain grades are used only in a few product categories. For example, the only secondary uses of mixed paper are in the manufacture of tissue and recycled paperboard. OCC is at the other extreme: it is an input for the manufacture of almost every product category, with the exception of newsprint and bleached paperboard (which uses only virgin paper inputs). Patterns of reuse reflect considerations of technical feasibility, cost, and consumer preference. The next section discusses the use of secondary paper and paperboard, so the perspective shifts from secondary materials to products, beginning with newsprint.

B.2.1 Production of Paper and Paperboard Products from Secondary Materials

B.2.1.1 Newsprint

ONP is virtually the only recycled wastepaper used in the manufacture of newsprint (see Table B-2). In 1970, U.S. newsprint manufacturers used 371,000 tons of ONP in the production of 3.464 million tons of newsprint for a utilization rate of 10.7 percent (Franklin Associates, 1989). Table B-2 shows that the use of ONP increased severalfold by 1987: 1.386 million tons of ONP were used in the production of 5.843 million tons of domestic newsprint, for a secondary materials utilization rate of 23.7 percent (Franklin Associates, 1989). Capacity to produce newsprint in the U.S. in 1987 was 5.9 million tons. Only 1.5 million tons could be attributed to the 7 recycled mills in operation in 1987 that used either 100 percent recycled fiber or a significant portion of ONP, leaving almost 75 percent of the market to mills using virgin inputs (U.S. Congress, 1989). By 1990, total annual capacity for U.S. newsprint mills is projected to be 7.021 million tons. Of this, 1.434 million tons should consist of recycled newsprint, for a secondary materials utilization rate of 20.4 percent. The capacity of mills using secondary materials is approximately 20 percent that of mills using virgin inputs (Franklin Associates, 1989).

Table B-3 contains a common list of barriers to increasing the use of ONP: the addition of capacity favors expansion rather than greenfield construction; mills are locked into virgin pulp supply arrangements either through vertical integration or contracts; the supply of quality ONP is perceived to be unreliable; and the current location of mills[3] implies high transportation costs for ONP. For a substantial increase in the relative rate of secondary material use to occur, it is not enough for the number of mills using secondary material to increase: the economics of new mills must change.[4]

The barriers to increasing the use of ONP may be less effective in the future than they were in the past (even as recently as several years ago). The U.S. paper industry is rapidly increasing recycling capacity,[5] which is leading to unprecedented growth in waste paper demand

[3] Newsprint mills using virgin fiber tend to be located near forest and water resources, far from the population centers that are the source of ONP.

[4] Secondary-pulp-using mills could increase the proportion of secondary pulp. The technological knowledge exists to manufacture newsprint from 100 percent ONP using a deinking process patented by Garden State Paper Company; however, the economic barriers are so high that publishers are not yet increasing their demand for ONP (U.S. Congress, 1989).

[5] Eighteen producers of newsprint plan to purchase deinking units in the near future (Hill and Knowlton, 1990).

TABLE B-3. BARRIERS TO INCREASED USE OF WASTE PAPER AND PAPERBOARD

Waste Paper Product	Residential		Commercial	
	Barriers	Reason	Barriers	Reason
Newsprint	Very High	Too expensive to expand capacity Integrated operations with virgin mills Long-term contracts with virgin mills Quality of the additional ONP supply Economics of transportation unfavorable	Very High	Too expensive to expand capacity Integrated operations with virgin mills Contracts with virgin mills Quality of added ONP supply Economics of transportation unfavorable
Fine Printing and Writing Papers	High	Exhausted supply Competition (tissue, exports) Limited sorted office paper	High	Exhausted supply Competition (tissue, exports) Limited sorted office paper
Tissue	High	Consumer preference	High	Exhausted supply Competition, exports Limited sorted office paper
Kraft and Packaging Papers			Very High	Performance requirement Competition from plastic
Unbleached Kraft Paperboard			High	Performance requirement
Semichemical Paperboard			High	Performance requirement
Bleached Paperboard			Very High	Legal sanitary requirements
Recycled Paperboard	High	Consumer preference Sanitary, health, weight, economic, and performance	High	Competition (plastics, virgin)
Construction Paper and Board			Very High	Declining industry Competition from fiberglass

by domestic mills (Franklin Associates, 1990). Industry executives predict that approximately 33 percent of all newsprint used in the U.S. will be recycled back into newsprint in 1995, up from an 11 percent rate in 1990. They expect this figure will reach 41 percent by the year 2000 and then level off because of supply limitations (Hill and Knowlton, 1990).

Addressing the issue of quality, the Northeast Recycling Council (NERC)[6] is committed to ensuring that existing supplies of ONP meet the "Number 6 News" specification as defined in the Guidelines for Paper Stock: PS-88 Domestic Transactions. Furthermore, member states (Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode island, Vermont, and the Virgin Islands) share a common long-term goal to develop and organize a regional ONP supply that meets, at a minimum, the "Number 89 Special News" specifications as defined in the guidelines. Several member states have funding available to assist the development of marketing cooperatives that provide technical assistance to localities to achieve this goal (NERC).

A leadership opinion study (that polled 26 of 36 newsprint producers in the U.S. and Canada) conducted for the Black Clawson Company, one of the largest North American manufacturers of recycling machinery, indicates that newsprint company executives strongly endorse newsprint recycling and predicts that the rate of recycling newsprint back into newsprint will triple by 1995. Although 30 percent of the surveyed producers currently produce recycled newsprint, nearly every producer expects to make recycled newsprint by 1995. Roughly one-third anticipate producing nothing but recycled newsprint in 1995; half will make both recycled and virgin newsprint. Only one of the 26 responding firms states said that it will not produce recycled newsprint. Industry leaders hold these positive views even though they are concerned about costs, availability of adequate supplies of ONP, and the quality of post-consumer newsprint collected for recycling (Hill and Knowlton, 1990).

Some restructuring of the industry may occur. Carl C. Landegger, Chairman of Black Clawson, comments, "In total, the amount of ONP currently bypassing the solid waste stream appears to be seven million tons out of the 13.6 million tons used in the U.S. in 1989. This is why newsprint industry leaders predict supplies of ONP will be tight when newsprint to newspaper recycling approaches the 40 percent level [as promoted by the American Paper Institute]" (Hill and Knowlton, 1990). Some producers are worried that as demand increases for ONP, the price will also increase. Concerns over long-range ONP supply are prompting newsprint producers to consider purchasing a waste paper dealer to assure a dependable source of old newspapers (Hill and Knowlton, 1990).

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[6] Established in 1987.

B.2.1.2 Fine Printing and Writing Papers

Products manufactured from recycled fine printing and writing papers are primarily publishing and office products, such as books, brochures, magazines, stationery, commercial printing, office papers, forms, bond, cotton fiber, file folders, computer paper, and envelopes (EPA, 1988).

The higher grades of wastepaper, pulp substitutes and high-grade deinking paper, are virtually the only types of recycled wastepaper used to manufacture fine printing and writing papers. In 1970, U.S. producers of fine printing and writing papers used 736,000 tons of pulp substitutes and high-grade deinking paper in a total production of 10.904 million tons, for a utilization rate of 6.7 percent (Franklin Associates, 1989). Table B-2 shows that the use of wastepaper had increased in 1987; 970,000 tons of pulp substitutes (74 percent of the wastepaper used) and 336,000 tons of high-grade deinking paper (25 percent of the wastepaper used), along with 12,000 tons of OCC, were used in a total production of 20.778 million tons of fine printing and writing paper. Because the total production increased relatively more than the use of wastepaper, the secondary materials utilization rate actually decreased to 6.3 percent (Franklin Associates, 1989).

Increasing this utilization rate may not be possible immediately. Secondary fiber mills compete with the larger, integrated world-class mills by offering high quality and low-cost secondary fiber (U.S. Congress, 1989). Competition from tissue paper manufacturers and increased exports can increase the cost of secondary fiber. Also, according to the Office of Technology Assessment, most of the pulp substitutes and high-grade deinking paper generated appears to be used already. The only immediate means to increase the supply of secondary fiber is to increase the supply of products manufactured at converting and printing plants and paper mills, thereby generating the cuttings that are pulp substitutes. Otherwise, increasing recycling of sorted high-quality office paper is necessary to yield the needed secondary fiber (U.S. Congress, 1989).

U.S. mills' capacity to produce fine printing and writing paper in 1988 was 22.7 million tons, but only 9 mills had deinking facilities. Eighteen mills, however, had the capability to produce products containing at least 50 percent wastepaper but had a combined capacity of only one million tons annually, leaving almost 96 percent of the market to mills using virgin inputs (U.S. Congress, 1989).

B.2.1.3 Tissue Paper

Toilet and facial tissue, napkins, toweling, diapers, wipes, and other sanitary papers are the primary products manufactured from tissue paper (U.S. Congress, 1989).

Tissue paper manufacturers use primarily the higher grades of wastepaper, pulp substitutes, and high-grade deinking paper, while using the lower three grades to a lesser extent. In 1970, U.S. tissue paper manufacturers used 819,000 tons of pulp substitutes and high-grade deinking paper, 76,000 tons of ONP, 69,000 tons of OCC, and 7,000 tons of mixed papers in the total production of 3.178 million tons of tissue paper, for a utilization rate of 26.1 percent (Franklin Associates, 1989). Table B-2 shows that the use of wastepaper in 1987 increased to 2.246 million tons; 1.051 million tons of high-grade deinking paper (47 percent of the wastepaper used), 726,000 tons of pulp substitutes (32 percent), 209,000 tons of OCC (9 percent), 197,000 tons of ONP (8 percent), and 63,000 tons of mixed paper (3 percent) were used in a total production of 5.301 million tons of tissue paper, for a secondary materials utilization rate of 45 percent (Franklin Associates, 1989).

The problems with increasing this utilization rate are similar to those encountered by the fine printing and writing paper manufacturers. Tissue paper manufacturers compete with manufacturers of fine printing and writing papers for wastepaper. Also, because the Office of Technology Assessment states that most of the pulp substitutes and high-grade deinking paper generated appears to be collected already, increasing the supply of cuttings generated as waste from converting and printing plants and paper mills, as well as increasing the recycling of sorted high quality office paper, is the route that stands to yield the needed secondary fiber (U.S. Congress, 1989). An alternative to increasing the supply of pulp substitutes and high-grade deinking paper is using lower grades of wastepaper in the manufacture of tissue paper. Currently, the only companies employing this method are companies marketing their products to commercial establishments, which do not require the soft, white tissue that can only be produced by the higher grades of wastepaper or virgin materials. Consumer preference strongly influences the decisionmaking of tissue manufacturers on this matter (U.S. Congress, 1989).

U.S. capacity to produce tissue paper in 1988 was 5.8 million tons, but only 20 to 40 mills manufactured products containing at least 25 percent wastepaper. Some mills employ an increased percentage of wastepaper using proprietary technology (U.S. Congress, 1989).

B.2.1.4 Kraft and Packaging Paper

The products manufactured from kraft and packaging paper are primarily sacks, bags, wrapping paper, shipping sacks, and industrial papers (EPA, 1988).

Because of the high performance requirements demanded of kraft and packaging paper, pulp substitutes and OCC are the dominant grades of wastepaper used to manufacture this paper; high-grade deinking paper is used to a lesser extent. Table B-2 shows that 5.1 million tons of kraft and packaging paper were manufactured in 1987, with an annual secondary materials utilization rate of approximately 5 percent (U.S. Congress, 1989). Barriers to increasing this rate are the strength requirement of this paper and the strong competition from plastic bag manufacturers faced by kraft and packaging paper bag manufacturers (U.S. Congress, 1989).

B.2.1.5 Unbleached Kraft Paperboard

Linerboard (outer facing for corrugated and solid fiber boxes) and folding cartons are the primary products manufactured from unbleached kraft paperboard (U.S. Congress, 1989; API).

OCC is the dominant grade of wastepaper used to manufacture unbleached kraft paperboard. In 1970, U.S. unbleached kraft paperboard manufacturers used 162,000 tons of OCC in the total production of 11.541 million tons of unbleached kraft paperboard for a utilization rate of 1.4 percent (Franklin Associates, 1989). Table B-2 shows that the use of wastepaper increased to 1.9 million tons in 1987, virtually all of which was OCC. The manufacture of 18.898 million tons of kraft and packaging paper included 1.755 million tons of OCC (92 percent of the wastepaper used) for a secondary materials utilization rate of 10.1 percent (Franklin Associates, 1989). Because of the high performance requirements demanded of unbleached kraft paperboard, this rate is not expected to increase. Nevertheless, ongoing research is studying ways to enhance the strength of OCC, including using heat and higher pressure in board production, press drying in papermaking, separation of the linerboard from the weaker medium, and enhancement with chemical additives (U.S. Congress, 1989).

B.2.1.6 Semichemical Paperboard

The center fluting in corrugated boxes is the primary product manufactured from semichemical paperboard (API).

OCC is the dominant grade of wastepaper used to manufacture semichemical paperboard. In 1970, semichemical paperboard manufacturers' secondary materials utilization rate was approximately 21 percent (U.S. Congress, 1989). Table B-2 shows that this rate increased to

32 percent in 1987. Manufacturers used approximately 1.8 million tons of wastepaper, virtually all of which was OCC. The manufacture of 5.6 million tons of semichemical paperboard included 1.645 million tons of OCC (91 percent of the wastepaper used) (Franklin Associates, 1989).

Technically, manufacturers of semichemical paperboard could achieve a higher utilization rate. The higher-strength and durability demanded by U.S. shipping and legal requirements are possible only by including low proportions of recycled material in the final product (U.S. Congress, 1989).

B.2.1.7 Bleached Paperboard

Sanitary packages such as milk cartons, frozen food cartons, and containers for moist, liquid, and oily foods and folding cartons and food service items (cups and plates) are the primary products manufactured from bleached paperboard (U.S. Congress, 1989; API).

In 1987, U.S. manufacturers produced 4.3 million tons of bleached paperboard using virgin materials exclusively (U.S. Congress, 1989). Because of the strict legal sanitary requirements, any significant use of secondary fiber is unlikely (U.S. Congress, 1989).

B.2.1.8 Recycled Paperboard

Test liners, corrugating medium,[7] filler chipboard for solid fiber boxes, folding cartons, rigid boxes, gypsum wallboard, paper tubes and drums, panelboard, set-up boxes,[8] and tablet backing are the primary products manufactured from recycled paperboard (U.S. Congress, 1989).

ONP is used to manufacture folding boxboard, set-up boxboard, gypsum wallboard facing, and tube can and drum paperboard (Franklin Associates, 1989). Otherwise, OCC and pulp substitutes are the dominant wastepaper grades in many paperboard products (Franklin Associates, 1989). Almost 50 percent of all wastepaper recycled in the U.S. is used to manufacture recycled paperboard; the process uses no virgin raw materials (U.S. Congress, 1989). In 1970, manufacturers used 7.291 million tons of wastepaper in the total production of 6.981 million tons of recycled paperboard: 1.183 million tons of pulp substitutes, 2.995 million tons of OCC, 1.437 million tons of ONP, and 1.676 million tons of mixed papers (Franklin

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[7] A corrugated medium is the corrugated or fluted paperboard used by corrugating plants to make corrugated combined board, corrugated wrapping, etc. (Franklin Associates, Ltd. 1982).

[8] Set-up boxboard is boxes in rigid form as contrasted with folding or collapsible boxes, made from a paperboard that can be a solid or combination board ranging in thickness from 0.016 to 0.065 of an inch and weighing 60 to 206 pounds per 1,000 square feet. Stiffness, rigidity, and resistance to abuse are essential qualities. The class includes plain chipboard, filled newsboard, single news vat-lined chipboard, and single white vat-lined chipboard (Franklin Associates, 1982).

Associates, 1989). Table B-2 shows that the 1987 production of recycled paperboard increased to 8.508 million tons, using 9.121 million tons of wastepaper: 5.258 million tons of OCC, 1.641 million tons of mixed paper, 1.274 million tons on ONP, 832,000 tons of pulp substitutes, and 116 million tons of high-grade deinking papers (Franklin Associates, 1989).

The use of recycled paperboard for packaging products has been increasing as industries attempt to lower costs (U.S. Congress, 1989). Competing plastics and virgin paperboard industries cut into the recycled paperboard market, particularly in the packaging of high-quality goods. In this case, the manufacturer tends to disdain recycled paperboard for fear that the consumer will consider the product an inferior good. Secondary limitations on the use of recycled paperboard are sanitary, health, weight, economic, and performance considerations (U.S. Congress, 1989).

B.2.1.9 Construction Paper and Board

Roofing, siding, wallboard, and insulation board are the primary products manufactured from construction paper and paperboard (U.S. Congress, 1989).

In 1970, U.S. manufacturers produced 3 million tons of construction paper and board. That production steadily decreased until only 1.2 million tons were manufactured in 1987. The manufacturing process used approximately 900,000 tons of wastepaper of all grades, including 277,000 tons of ONP and 232,000 tons of OCC, for a secondary materials utilization rate of 75 percent. Because of competition from fiberglass and other materials, the construction paper and board industry is expected to continue its decline and, therefore, its market for wastepaper (U.S. Congress, 1989).

B.2.2 Net Exports of Wastepaper

Countries that lack significant forest resources, such as Mexico, Korea, Taiwan, Japan, Italy, and Venezuela, rely on imports of U.S. wastepaper as raw material inputs to their paper and paperboard mills (Franklin Associates, 1982). Countries in the Far East accounted for more than half of U.S. exports of wastepaper in 1987 (U.S. Congress, 1989). Other conditions exist that cause countries to import U.S. wastepaper: the gap in balance of trade with the U.S., the value of their currency versus the U.S. dollar, and the excess cargo room in ships making return trips to their countries from the U.S. (Franklin Associates, 1989).

OCC dominates the export market, claiming about 40 percent of wastepaper exported. Mixed paper and ONP are next, with each comprising approximately 20 percent of the market;

pulp substitutes and high-grade deinking paper share the remaining 20 percent (U.S. Congress, 1989).

U.S. exports of wastepaper increased in 1987 to approximately 18 percent of wastepaper recovered, compared with only 3 percent in 1970. Export amounts are calculated by determining the net quantity exported—total exports less the quantity imported of that material. In 1970, exports of wastepaper totalled 341,000 tons; that figure had increased to 4.295 million tons by 1987 (EPA, 1988). Exports of ONP from the United States to Canada may reach 700,000 tons in 1995 (Franklin Associates, 1990).

Increasing exports of wastepaper from the U.S. is subject to the cyclical demands of foreign nations for these goods. Nevertheless, wastepaper exports to foreign nations should continue to increase, although the recent glut of ONP has reduced export prices (U.S. Congress, 1989).

B.3 CURRENT AND HISTORICAL STATISTICS ON SECONDARY MATERIALS

B.3.1 Old Newspaper (ONP)

Over the last 15 years the quantity of ONP generated has increased along with the quantity recovered as shown in Figure B-2. In 1987, the quantity of ONP diverted from the solid waste stream reached a record of 4.3 million tons. The ONP recovery rate has tended slightly upward as shown in Figure B-3. In 1987, the ONP recovery rate was 32 percent (Franklin Associates, 1989). Some observers speculate that the upper limit of the recovery rate is 50 to 55 percent, although others assert that a 75 percent recovery is possible (Franklin Associates, 1989).

Figure B-4 demonstrates that ONP prices fluctuated dramatically in a cyclical pattern between 1970 and 1988. Chicago manufacturers paid the highest prices in January 1978—over $80 per ton. More typically, however, manufacturers' prices ranged from about $20 per ton to about $60 per ton. The lows have been increasing over time: the lows in the early 1970's were under $20 per ton, increasing to approximately $25 per ton in the early- to mid-1980's.

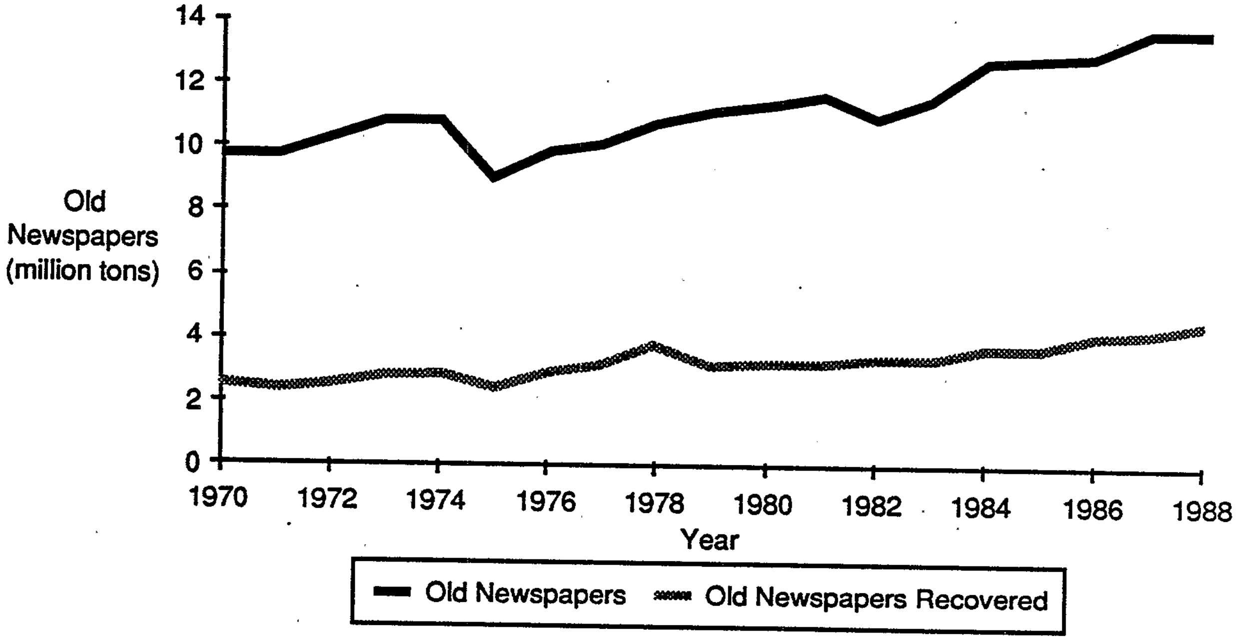


Figure B-2. Old Newspaper Generation and Recovery
Source: Bingham and Chandran, 1990.

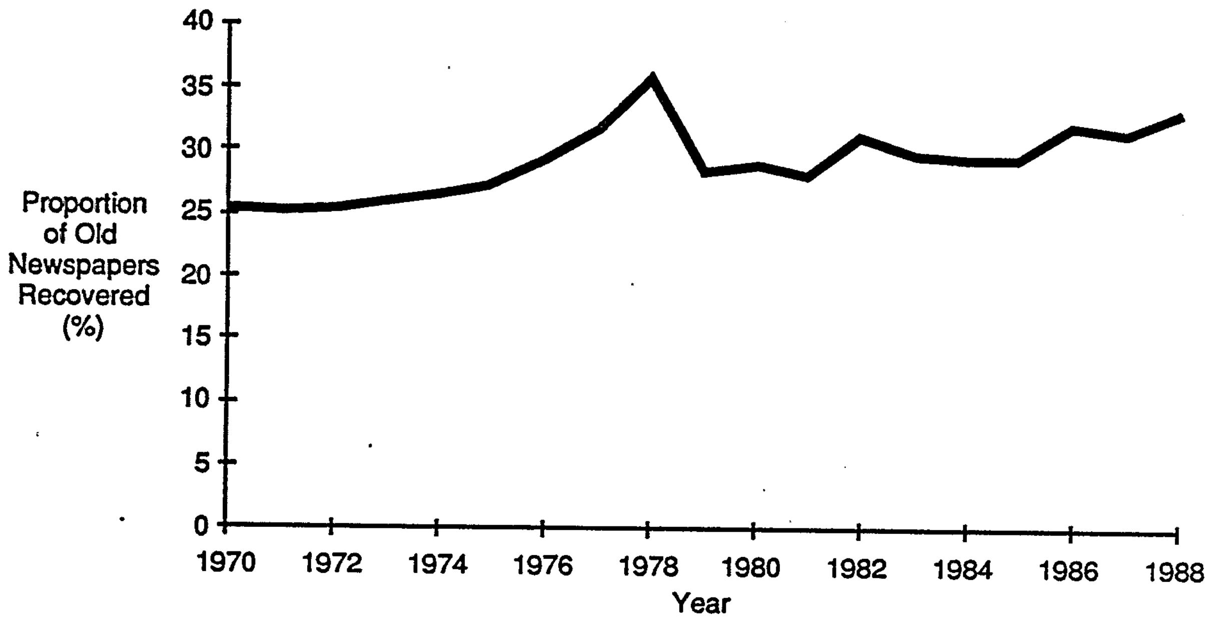


Figure B-3. Old Newspaper Recovery Rate
Source: Bingham and Chandran, 1990.

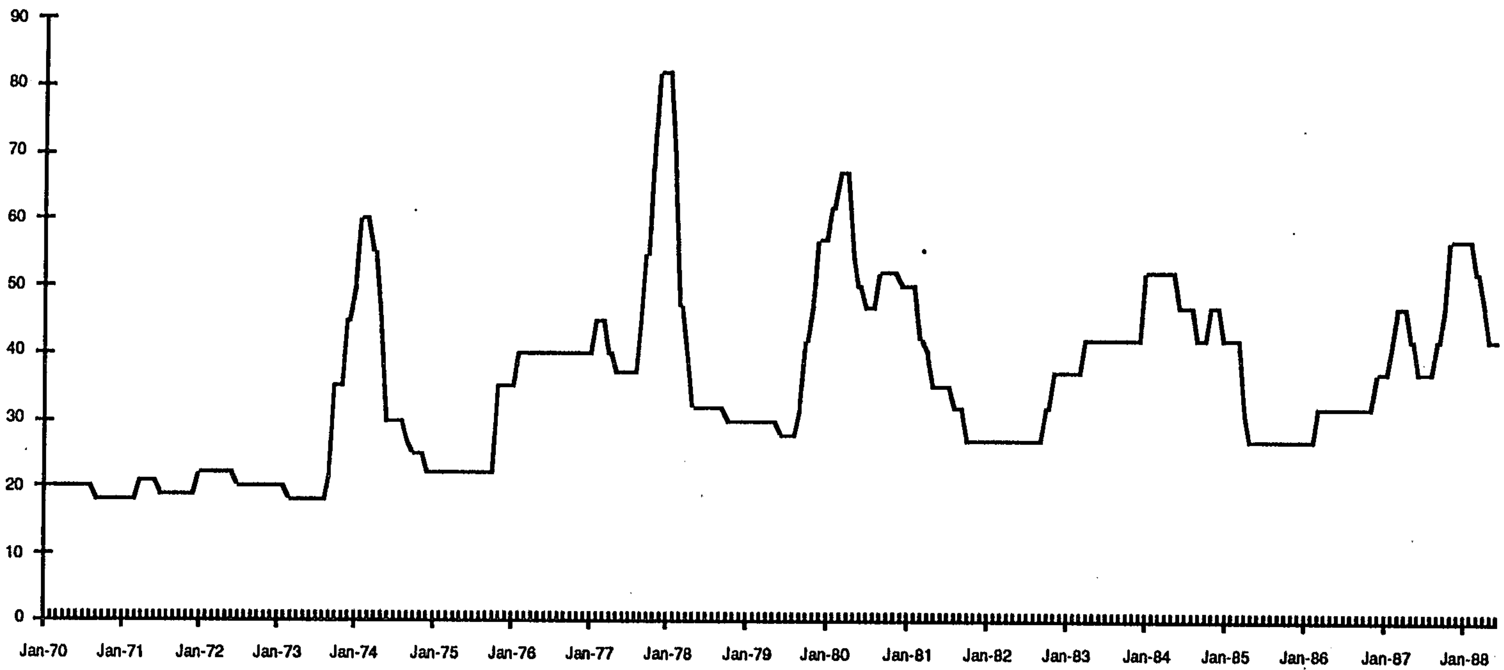


Figure B-4. Newsprint Prices in Chicago, 1970 to 1988
Source: Bingham and Chandran, 1990.

The increased public consciousness of the U.S. solid waste crisis contributed to the 1989 glut in the ONP market. State and local laws encouraging or mandating recycling created a tremendous oversupply of ONP, because no corresponding demand for this material was stimulated. Foreign demand for ONP also decreased during 1989, compounding the problem (Franklin Associates, 1989).

The oversupply of ONP caused market prices for ONP to fall drastically. In June 1988, a Barberton, Ohio, recycling center received $30 a ton for ONP. By late July 1989, the same center was paying a broker $10 a ton to take the paper away. The newspaper glut cost municipalities approximately $100 million in lost revenue for 1989 (Paul, 1989). Export prices of wastepaper, particularly ONP, also decreased due to the excess supply (Franklin Associates, 1989).

Figure B-5 shows the amount of ONP used by paper and paperboard mills, the quantities used in manufacturing products unrelated to paper and paperboard, and the quantities exported, since 1977. Of the 4.3 million tons of ONP recovered in 1987, 1.4 million tons were recycled into newsprint, 197,000 tons into tissue, 9,000 tons into unbleached kraft paperboard, 1.3 million tons into recycled paperboard, 277,000 tons into construction paper and paperboard, and 300,000 tons into other uses; 840,000 tons were exported. One market for ONP that is unrelated to newsprint and other types of paper and paperboard is cellulose insulation for buildings, for which EPA specifies a minimum content standard of 75 percent recycled newsprint. Other products that use secondary newsprint include animal bedding, artificial fire logs, mulch, and worm bedding. Research is under way to test the feasibility of using ONP to clean up spills of hazardous liquids and sludges, as well as using up to 5 percent ONP in the manufacture of linerboard (Mullet, 1989).

Consumption of ONP by U.S. newsprint manufacturers is expected to increase by over 1 million tons between 1988 and 1995, a 71 percent increase. The demand for ONP for other uses (such as as animal bedding, hydromulch, and molded pulp products) will gradually accelerate (starting in 1991) to 50-plus percent in 1995.[9] The combination of all of these factors leads to a projected 1995 recovery of 8.0 million tons or 51.6 percent of new supply of newsprint (Franklin Associates, 1990).

[9] An alternative prediction is less bullish: because most of the firms that manufacture these products have abundant supplies of ONP, the outlook for increasing the amount of ONP recycled by these industries is not bright (Mullet, 1989).

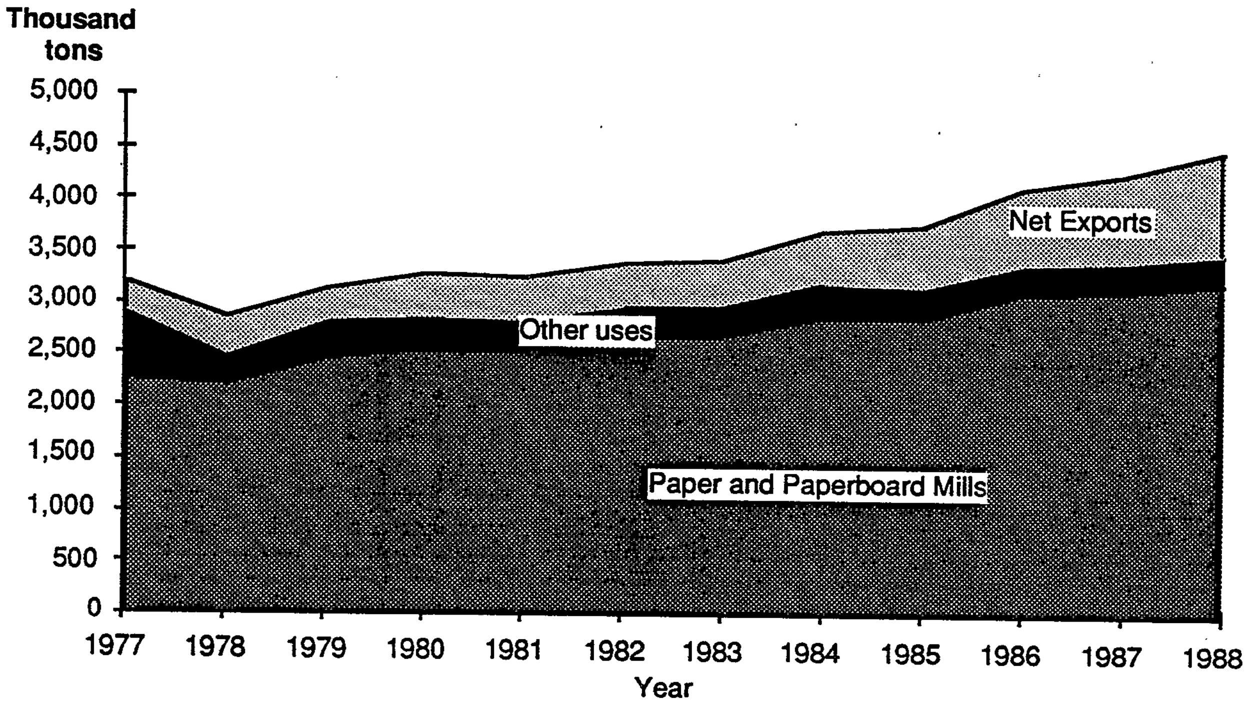


Figure B-5. Utilization of Old Newspapers
Source: Franklin Associates, Ltd., 1989.

B.3.2 Old Corrugated Containers (OCC)

Over the last 15 years, the quantity of OCC generated has, like ONP, increased along with the quantity recovered as shown in Figure B-6. The OCC recovery rate has tended slightly upward as shown in Figure B-7. In 1987, the OCC recovery rate was 48 percent (Franklin Associates, 1989).

Figure B-8 shows the amount of OCC used by paper and paperboard mills, as well as the quantities exported, since 1970. Of the 11.1 million tons of OCC recovered in 1987, 290,000 tons were recycled into paper products, 1.8 million tons into unbleached kraft paperboard, 1.6 million tons into semichemical paperboard, 5.3 million tons into recycled paperboard, and 232,000 tons into construction paper and paperboard; 1.9 million tons were exported (Franklin Associates, 1989).

As with ONP, the capacity to utilize corrugated as a fiber furnish is increasing very rapidly. These increases are being driven by increased demand for container board, the economics of fiber supply, and the ability of the paper industry to increase production of linerboard and corrugating medium by incremental expansions and "greenfield" (new) mills. The projected capacity for 1995 and estimated actual usage indicate continued very strong increases for corrugated recycling, most of which will be post-consumer OCC because box plant cuttings are already fully utilized (Franklin Associates, 1990)

The recovery of corrugated is projected to be 18.8 million tons in 1995, a 51.6 percent increase relative to 1988 (12.45 million tons). Over the same period, containerboard new supply may increase at less than half that rate, by 19.8 percent. Consequently, recovery rates may increase to 63 percent of OCC. Using present manufacturing techniques, the recovery of OCC will approach the limits of recovery by 1995 (Franklin Associates, 1990).

B.3.3 Mixed Papers

Because the higher grades of wastepaper—high-grade deinking paper and pulp substitutes—are in short supply, manufacturers are developing techniques to improve the recyclability of mixed paper. Programs are starting in office buildings and homes to separate higher quality mixed paper from other discards (API). As Figure B-9 illustrates, the recovery of office paper has slowly increased in the last five years, but it is far outpaced by the increasing quantities of office paper discarded (Franklin Associates, 1989). Of the 2.4 million tons of mixed paper recovered in 1987, 63,000 tons were recycled into tissue paper and 1.641 million tons recycled into paperboard; 707,000 tons were exported (Franklin Associates, 1989).

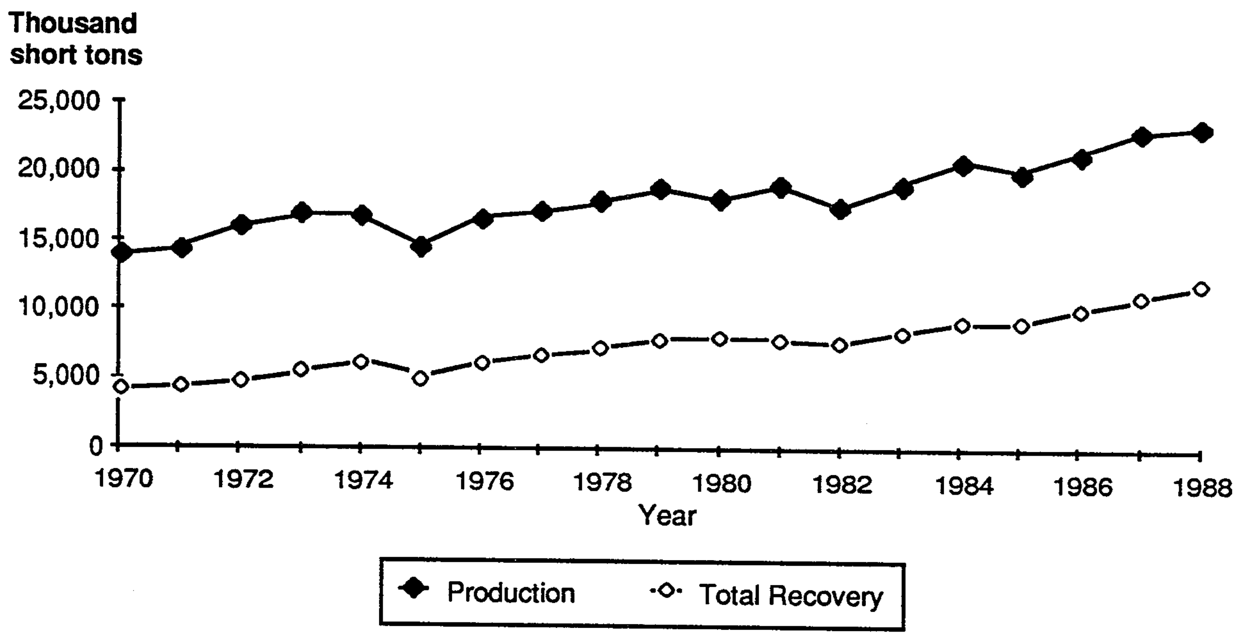


Figure B-6. Used Corrugated
Source: Franklin Associates, Ltd., 1989.

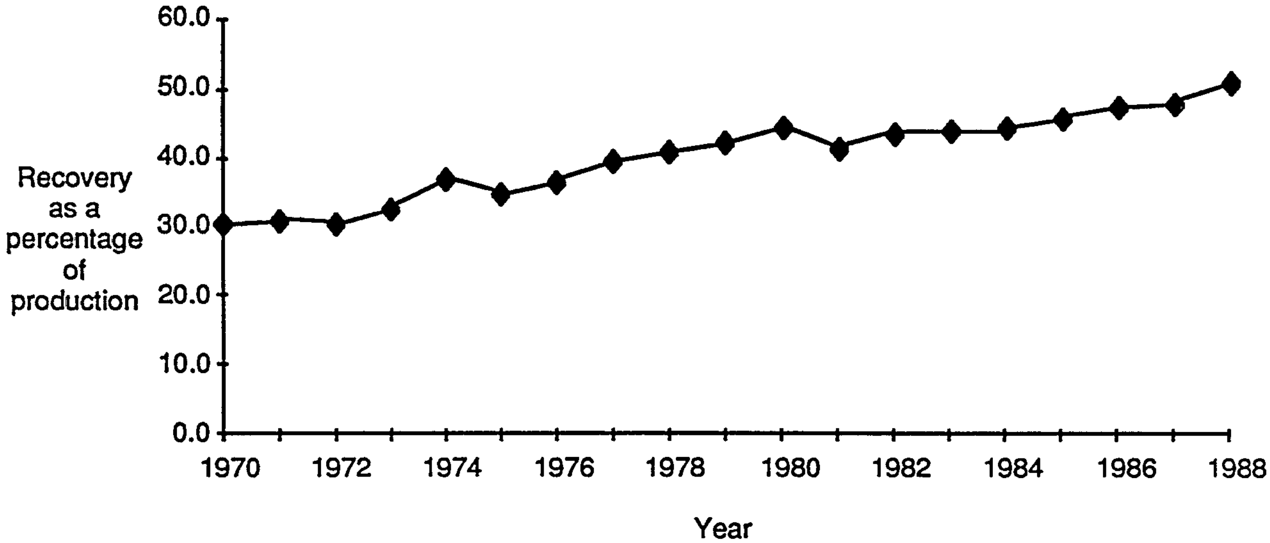


Figure B-7. Recovery of Used Corrugated Containers, 1970 to 1988 (in thousands of tons)

Source: Franklin Associates, Ltd., 1989.

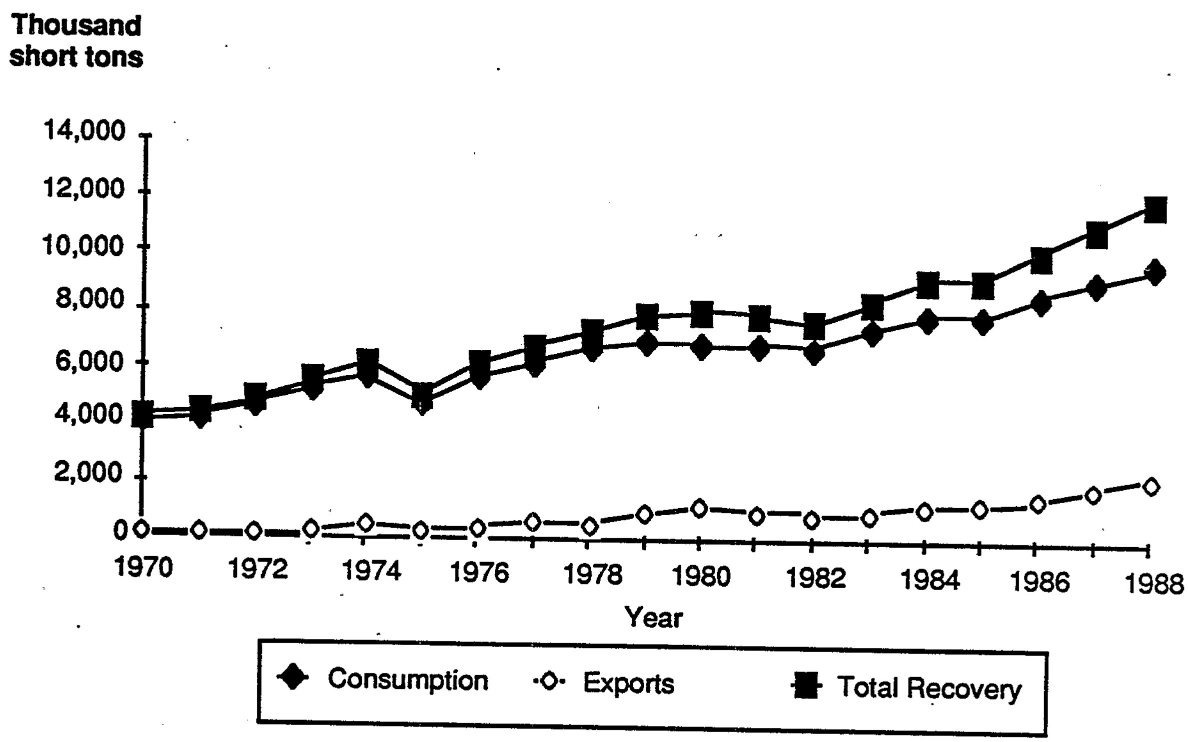


Figure B-8. Used Corrugated Containers
Source: Franklin Associates, Ltd., 1989.

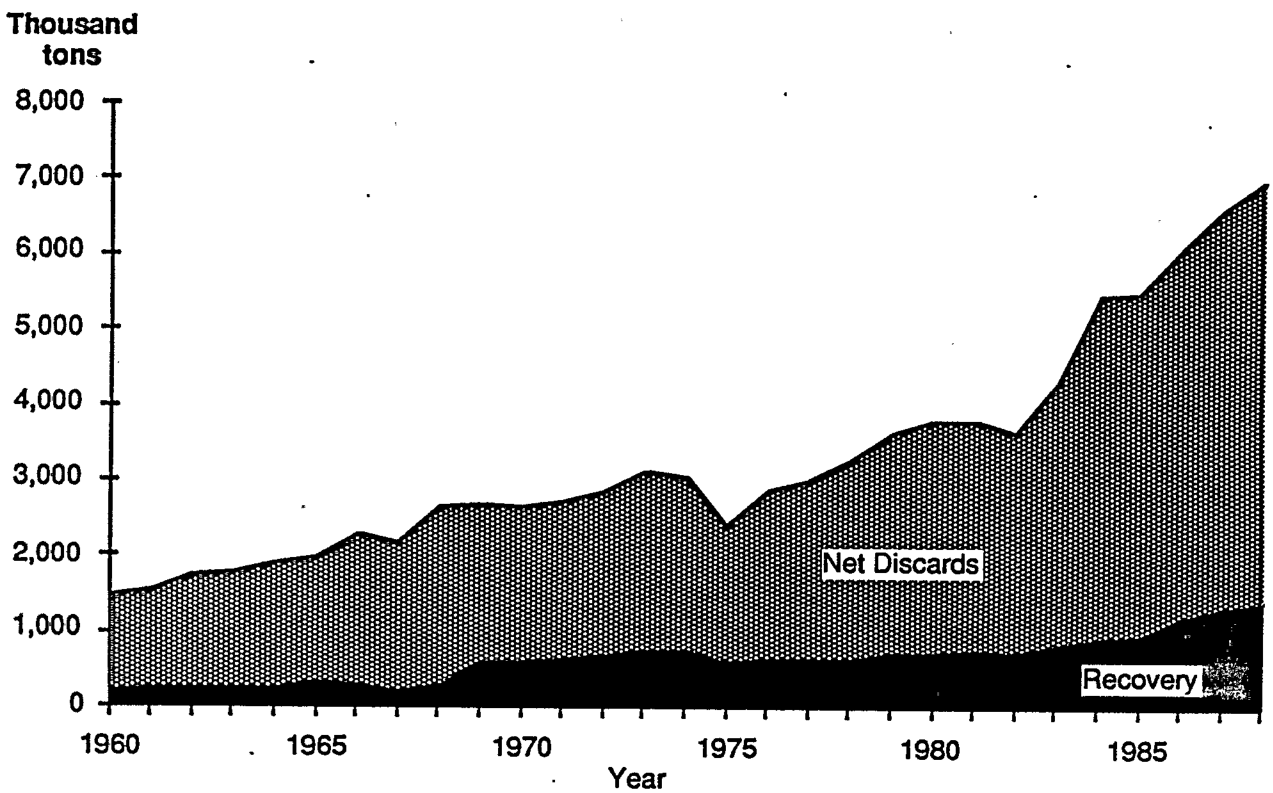


Figure B-9. Office Paper Recovery and Discards
Source: Franklin Associates, Ltd., 1989.

B.3.4 High-Grade Deinking Paper

The quantity of high-grade deinking paper recovered has increased over the last decade as shown in Figure B-10. The amount recovered tended slightly upward for the first 9 years but has begun to increase more dramatically in the last few years (Franklin Associates, 1989). Because all the high-grade deinking paper generated appears to be collected for recycling every year, this increase is probably due to an increased supply of products manufactured at converting and printing plants and paper mills (U.S. Congress, 1989).

Figure B-10 shows the amount of high-grade deinking paper consumed by paper and paperboard mills, as well as the quantities exported since 1976. Of the 2.072 million tons of high-grade deinking paper recovered in 1987, 336,000 tons were recycled into fine printing and writing paper, 1.1 million tons into tissue, 7,000 tons into kraft and packaging paper, 52,000 tons into unbleached kraft paperboard, 116,000 million tons into recycled paperboard, and 2,000 tons into construction paper and paperboard; 526,000 tons were exported (Franklin Associates, 1989).

B.3.5 Pulp Substitutes

Of the 3.2 million tons of pulp substitutes recovered in 1987, 970,000 tons were recycled into fine printing and writing paper, 726,000 tons into tissue paper, 374,000 tons into kraft and packaging paper, and 832,000 tons into recycled paperboard; 300,000 tons were exported (Franklin Associates, 1989).

B.4 RECENT MARKET INTERVENTIONS BY FEDERAL, STATE, AND LOCAL GOVERNMENTS

The recent period of falling ONP prices (see section B.3.1 above) and the associated glut raised concerns over the economic viability of residential recycling programs and the prospect of reduced participation rates in general as residents watched their carefully separated newspapers go to landfills and municipal waste combustors. Dane County, Wisconsin, temporarily lifted a ban on landfilling old newspapers after its newspaper broker halved the amount he would purchase. Youngstown, Ohio, stopped picking up old newspapers in July 1989 and asked its residents to store them, although soon it might ask residents to just throw them away (Paul, 1989). Many different programs have been considered by state and federal governments to stabilize the market for waste paper.

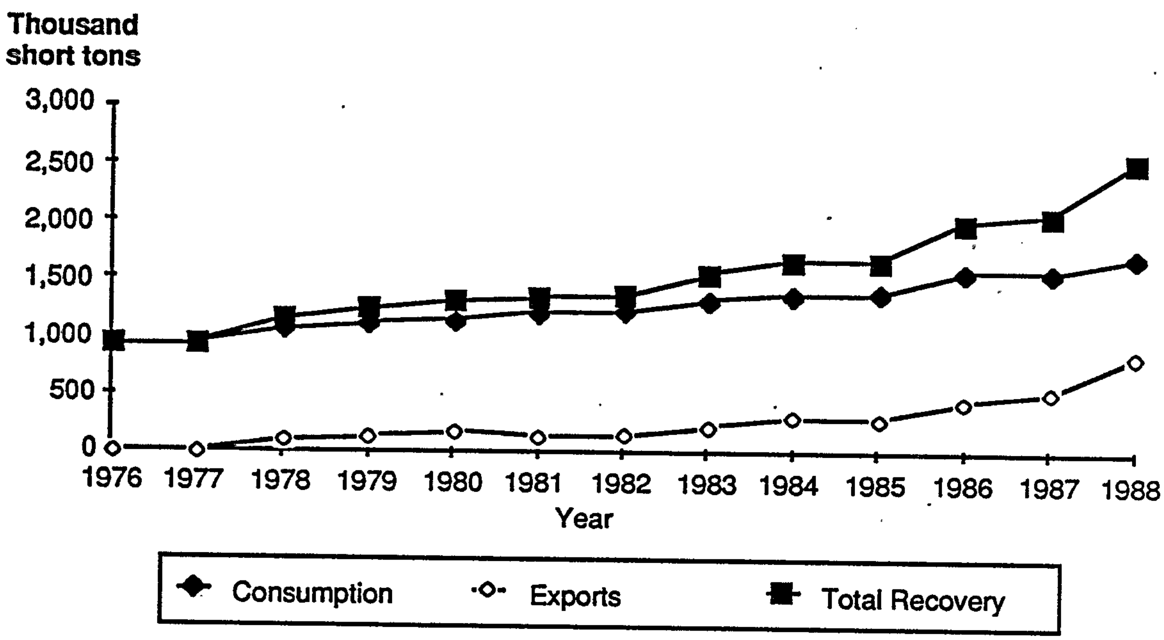


Figure B-10. High-Grade Deinking Paper Industry
Source: Franklin Associates, Ltd., 1989.

B.4.1 Incentives

In an effort to decrease the amount of paper and paperboard products combusted or landfilled, federal, state, and local governments have enacted legislation encouraging recycling of these products. One such type of state legislation provides incentives targeted toward manufacturers using secondary materials. These incentives include tax credits or exemptions, grants, low-interest loans, industrial bonds, and accelerated depreciation for recycling equipment purchases (EPA, 1988). This section focuses on subsidies that operate through the tax system.

The use of investment tax credits is under study by Massachusetts and New York and is already available in New Jersey, Oklahoma, Oregon, and Pennsylvania. In Oregon, under the Business Energy Tax Credit, companies can write off, over 5 years, 35 percent of the cost of any equipment used only for recycling; the Pollution Control Facility Tax credit is available to recycling facilities and materials recovery facilities. Both these programs have had minimal effects on recycling (U.S. Congress, 1989).

Illinois, New Jersey, and Wisconsin have passed sales tax exemptions. For example, in Wisconsin, collectors, processors, and manufacturers that use recycled materials are exempt from paying the state's 5 percent sales tax on equipment that uses recyclables or on the recyclables themselves (U.S. Congress, 1989). A study of the tax incentives offered by the state of Illinois found that these incentives did not prove effective, because tax liabilities are at most 1 percent of sales (EPA, 1988).

Indiana, Kentucky, North Carolina, and Wisconsin administer property tax exemptions that recyclers can claim; California provides a consumption tax credit, and North Carolina allows an income tax deduction (U.S. Congress, 1989).

B.4.2 Procurement

Governments attempt to stimulate recycling through the procurement practices of their offices. The idea is to increase the demand for recycled products by specifying a minimum-content standard of recycled materials in certain paper and paperboard products. Most of the recycled products the government purchases come from the print/writing and tissue paper grades (EPA, 1988).

As mandated by Section 6002 of the Resource Conservation and Recovery Act (RCRA), EPA published its final revised procurement guidelines for paper products in the June 22, 1988, *Federal Register*, requiring any government procurement agencies using federal funds to comply with minimum content standards in purchasing paper products costing more than $10,000 annually (*Waste Age* July, 1989). For example, most printing and writing paper products must be composed of at least 50 percent wastepaper and most tissue products composed of 20 to 40 percent wastepaper (EPA, 1988). The EPA guidelines are generating a great deal of interest in expanding mill capacity to use waste paper in the printing and writing grades as well as newsprint. The list of mills that are capable of producing recycled products is growing constantly in response to the markets created by the guidelines (Keller, 1989).

Programs at the state level include both set-aside and price preference programs. Set-aside programs allocate some fixed portion of the state's purchases to products containing recycled material, although the programs usually do not specify a set composition. Price preference programs in effect reduce by 5 or 10 percent the price of products containing recycled material, thereby allowing the recycled products to compete with virgin products that are cheaper. States with active paper procurement programs include California, Connecticut, Maryland, New York, Oregon, Rhode Island, and Washington. The following are considering similar legislation: Florida, Illinois, Iowa, Maine, Michigan, Minnesota, Missouri, New Jersey, Ohio, Texas, and Vermont (EPA, 1988).

B.4.3 Minimum Content Standards

Minimum content standards enacted in Connecticut require publishers that print or sell more than 40,000 copies of a newspaper in that state to manufacture newsprint containing at least 40 percent recycled material in at least 20 percent of the newspaper's sheets. The law takes effect by 1993 and increases the 40 percent recycled content requirement to 90 percent of the newspaper's sheets by 1997. Connecticut formed a task force to make recommendations on the implementation of the policy. The existing legislation does not include any penalties for noncompliance (Paul, 1989).

In 1988, Florida passed legislation requiring newspaper publishers to pay a tax of 10 cents per ton of the virgin content of the newsprint they consume.[9] This policy went into effect on January 1, 1989. Although the size of the tax is small, it provides a message to publishers indicating public preference for increased recycling. The recovery rate for

[9] Since the average price of newsprint is approximately $600/ton, this tax is equal to approximately 0.16 percent of the price of newsprint.

newspapers in Florida is currently estimated at 30 percent. If this recovery rate rises to 50 percent by 1992, the law will be rescinded; if the recovery rate does not reach 50 percent by 1992, the tax will increase to 50 cents per ton (U.S. Congress, 1989).

Most recently, California passed legislation in September 1989 that is similar to Connecticut's law. California's law requires publishers to use recycled newsprint for 10 percent of their newsprint needs in 1991. The amount used must increase by 10 percentage points per year until a rate of 50 percent is achieved in 1995. Violation of the law is classified as a misdemeanor and civil penalties of up to $1,000 per violation may be applied. The state will use revenue generated by penalties to defray the expenses of implementing the law. After the bill passed in California, Golden State, the largest user of ONP in California, announced it would conduct a preliminary study for a 300,000 ton a year addition to its facility (Kovacks, 1989).

In addition to these laws, three other states (New York, Illinois, and Wisconsin) have legislation pending that would encourage the use of recycled newsprint. For example, Wisconsin is considering legislation similar to California's law. The scheduled requirements for the use of recycled newsprint are the same as in California. The penalties under the proposed Wisconsin law are a function of the violator's total annual expenditures on newsprint and the difference between actual recycled newsprint purchases and required purchases. The state will use revenue generated by penalties for loans and grants to encourage recycling efforts.

One problem with state legislation is that newsprint mills are found in just 15 states, and only 7 of these currently have facilities for reprocessing old newspapers into newsprint. To meet a given state's requirement for recycling, newspaper publishers will purchase newsprint from the least-cost supplier who meets the state's minimum of recycled fiber. So, although a consumer purchases a newspaper in one state, the newspaper publisher may produce the newsprint in another state. Therefore, any particular state's initiative may not significantly affect the quantity of newspapers discarded in its solid waste stream. Another problem is the possible proliferation of a patchwork of unique state laws affecting a commodity typically traded across state lines.

At the federal level, Senator Boschwitz has introduced a bill (S1764) requiring certain newsprint consumers to use a minimum percentage of recycled newsprint. The required percentage increases over time. Senators Heinz and Wirth have introduced a bill (S1763) based on the concept of a marketable permit system that also would encourage the use of recycled newsprint.

House bill 3654, The Newspaper Incentive Recycling Conservation Act, provides a 10 percent investment tax credit for construction of recycling facilities and penalizes large newspapers (those with circulation of more than 150,000 copies daily) that fail to use recycled newsprint (Environmental and Energy Study Institute Seminar).

Conclusions about the level of the eventual use of secondary materials in the paper and paperboard industry and the stability of secondary markets for paper are very speculative. Nonetheless, predictions estimate that the use of ONP will increase in the early 1990's. If the market for ONP expands and stabilizes, perhaps the lessons learned by legislatures and businesses from the ONP market can be used to develop secondary markets for other grades of waste paper and paperboard.

APPENDIX C
GLASS INDUSTRY PROFILE

The glass industry produces three primary products: containers, pressed and blown glass, and flat glass. Figure C-1 shows the materials flow of the glass industry. These figures are for 1967 because more recent figures for all flows on the chart were not available. The basic flow of the industry remains the same today as in 1967.

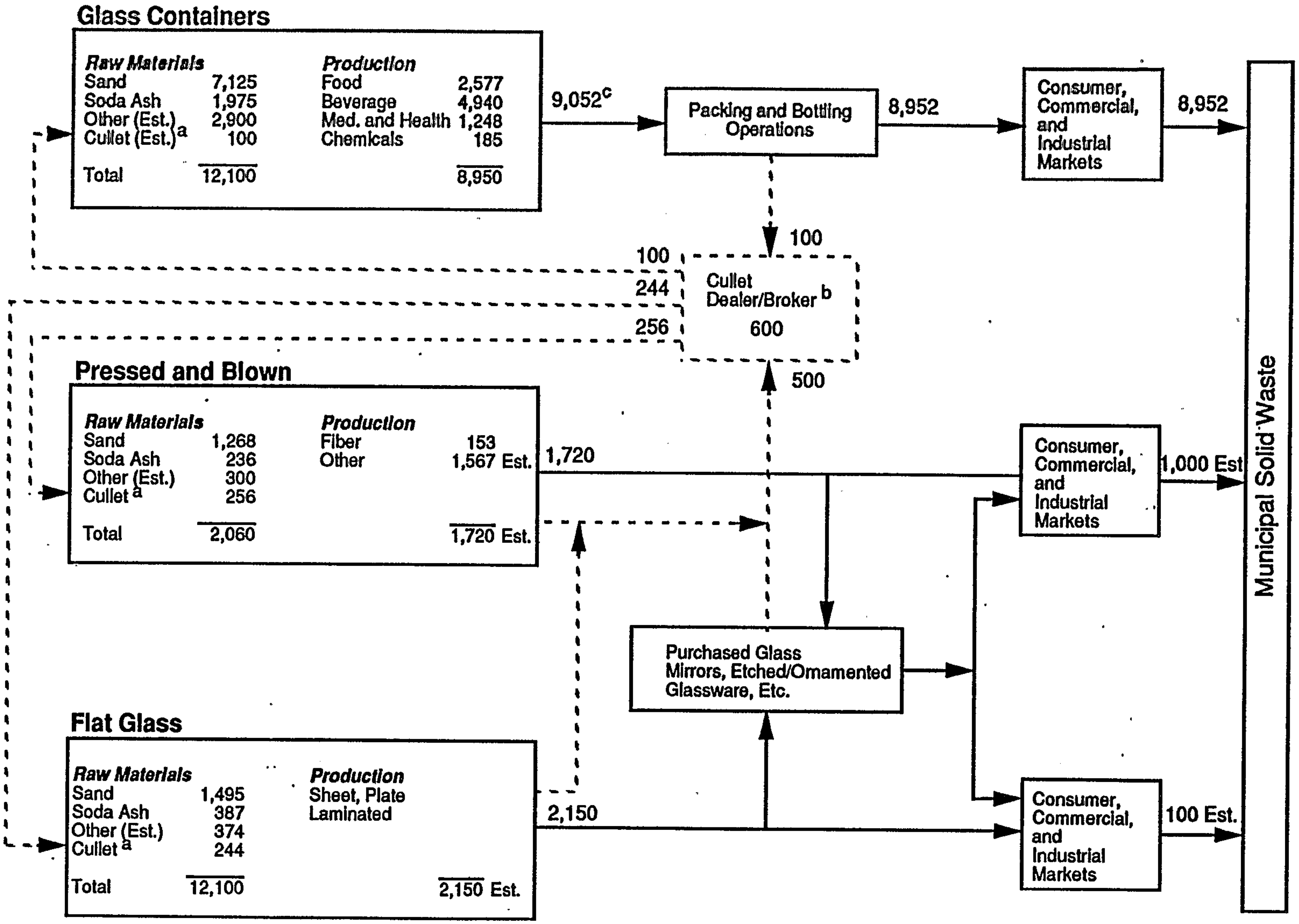
Containers, which make up 70 percent of all glass production and account for 90 percent of all glass in municipal solid waste (MSW), include beverage, food, drug, cosmetic, and chemical containers (EPA, 1988a). Container glass is usually one of three colors: flint (clear), amber (brown), or green. Glass containers comprise about 65 to 70 percent flint, about 23 percent amber, and about 13 percent green (EPA, 1988a). Table C-1 shows the shipments of glass containers by type of container for 1980 through 1986. A total of 41 billion glass containers was shipped in 1986, with beverage containers accounting for over 60 percent of those containers. Other sources estimate the total number of glass containers shipped in 1987 and 1988 at 40.5 billion and 41 billion, respectively, but do not provide a breakdown by container type (Franklin Associates, 1988; U.S. Congress, 1989).

Pressed and blown glass is divided further into three categories: (1) table, kitchen, art, and novelty glass; (2) lighting and electronic glass; and (3) glass fiber. The first category includes tumblers, stemware, tableware, cookware, ornamental and decorative products, novelty products, and ashtrays. Lighting and electronic glass includes such items as light bulbs, light tubes, and TV tubes. Glass fiber is used for insulation and manufacturing products.

Flat glass is also divided into three categories: (1) sheet or window glass, (2) plate or float glass, and (3) laminated glass. Sheet or window glass is used in buildings. Plate or float glass is used in automobiles, doors, and appliances. Laminated glass includes products like mirrors.

C.1 RAW MATERIALS

The primary raw material for glass production is silica sand. Other virgin raw materials include feldspar, limestone, and natural soda ash. Although possible, glass is seldom manufactured entirely from virgin materials. Instead, glass manufacturers also use cullet, which is crushed waste glass. Cullet melts at lower temperatures than virgin materials, and using 8 to 10 percent cullet in the inputs to a glass-making furnace improves the melting efficiency of the furnace and allows lower furnace temperatures. This results in energy savings, reduced air



Note: Solid lines indicate raw material and product flows to markets and MSW.
Dashed lines indicate cullet flows to recycling operations.

[a] Excludes internally produced and consumed cullet.

[b] Only about 1/6 of this is physically handled in dealer processing facilities.

[c] The difference between production and shipments is an inventory change.

Source: Darnay and Franklin, 1972, p. 71-1.

Figure C-1. Approximate Glass Industry Materials Flow, in 1,000 tons, 1967.

TABLE C-1. GLASS CONTAINER SHIPMENTS (MILLIONS OF CONTAINERS)

Type of Container	1980	1981	1982	1983	1984	1985	1986
Beverages	29,534	29,029	27,511	26,402	25,459	24,457	25,592
Soft drinks	8,330	8,676	8,787	9,017	8,867	8,652	8,941
Refillable	658	596	537	487	302	224	N/A
Nonrefillable	7,672	8,080	8,250	8,530	8,564	8,429	N/A
Beer	17,666	16,897	15,532	13,982	13,075	12,064	12,615
Refillable	269	226	273	356	500	269	N/A
Nonrefillable	17,396	16,671	15,259	13,626	12,575	11,795	N/A
Liquor	2,274	2,213	1,981	2,119	2,018	1,719	1,566
Wine	1,265	1,244	1,211	1,284	1,500	2,021	2,471
Food	12,857	13,123	13,108	12,713	13,028	12,054	12,640
Medicinal and health supplies	2,310	2,277	2,231	1,823	1,914	1,645	2,291
Chemical, household, and industrial	470	409	377	257	341	282	696
Toiletries and cosmetics	1,470	1,340	1,248	998	1,011	849	0
TOTAL	46,641	46,178	44,474	42,194	41,753	39,286	41,219

Source: Department of Commerce (in EPA, 1988a) emissions, and extended life of the refractory lining of the furnace (EPA, 1988c). The most common mix is 25 percent cullet (U.S. Congress, 1989).

Although cullet is 100 percent recyclable (i.e., one pound of cullet makes one pound of new glass), it is not efficient to use 100 percent cullet in furnace feed. One reason is that cullet lacks "fining" agents, which are necessary to reduce bubbles in the glass (U.S. Congress, 1989). Most importantly, however, the glass industry has strict specifications for cullet use in glass making. The cullet cannot be contaminated and must be separated by type of glass and color. Due to chemical differences, container glass cullet is not suitable for making other types of glass, and flat and blown glass cullet is not suitable for making container glass (EPA, 1988c). Color separation is critical for container glass. Table C-2 lists specifications for furnace-ready cullet for container glass. Because these specifications are so strict, glass manufacturers rely primarily on home scrap (scrap glass from their own processes) for cullet, rather than postconsumer recycled glass. The composition of home scrap is far more reliable than that of postconsumer cullet. To use postconsumer cullet, manufacturers must apply rigorous cullet recovery techniques to ensure that the cullet meets glass industry specifications.

C.1.1 Cullet Recovery Techniques

Techniques for recovering usable cullet from MSW include source separation, optical sorting, froth flotation, and hand sorting. The goal of cullet recovery techniques is to produce cullet that is color sorted and free of contamination, especially refractory materials (materials that don't melt completely in the furnace) and metal. For some applications, color separation is not necessary.

Source separation occurs when consumers separate glass from other recyclables and by color. Source separation is inexpensive and provides good gross separation of glass from other materials and by color. Nevertheless, it is not sufficient to meet the strict specifications for cullet use. Glass recovered by source separation may still contain contaminants, such as the metal rings on many beverage containers. Source separation is, however, a valuable first step.

An alternative to source separation is hand sorting. In hand sorting, workers sort glass pieces to remove contaminants and to separate by color. Larger pieces are easier to sort. Hand sorting probably produces the most reliably contaminant-free, color-sorted cullet, but it is very labor intensive. Hand sorting most often occurs at materials recovery facilities that receive clean commingled recyclable materials.

TABLE C-2. SPECIFICATIONS FOR FURNACE-READY CULLET

- Only container glass is acceptable.
- Permissible color mix levels:
  - flint glass

    95-100% flint; 0-5% amber; 0-1% green; 0-5% other colors
  - amber glass

    90-100% amber; 0-10% flint; 0-10% green; 0-5% other colors
  - green glass

    80-100% green; 0-20% amber; 0-10% flint or Georgia green; 0-5% other colors
- Glass must be free of excessive moisture.
- Glass must be free of any refractory materials. Can be rejected for any of the following reasons:
  - presence of any pottery, porcelain, china, dinnerware, brick, tile, or clay larger than 1 inch;
  - presence of more than one particle of any of the above materials larger than 1/8 inch, but less than 1 inch in a 200-pound sample;
  - presence of more than two grains of quartzite, sandstone, or sand pebbles larger than U.S. 16 mesh per 10 pounds of sample;
  - presence of any clay particles larger than U.S. 20 mesh or more than 50 particles larger than U.S. 30 mesh per 10 pounds of sample;
  - presence of any alumina silicate refractory heavy minerals larger than U.S. 30 mesh or more than 10 grains larger than U.S. 40 mesh per 10 pounds of sample;
  - presence of any alumina refractory heavy minerals larger than U.S. 40 mesh;
  - presence of zircon, cassiterite, chrome, or similar refractory particles larger than U.S. 60 mesh.
- Glass must be free of metallic fragments and objects. Can be rejected for any of the following reasons:
  - presence of any metal fragments or objects larger than 1.5 inches.
  - presence of more than one metallic particle or object larger than 3/8 inch but less than 1.5 inch per 200 pounds of cullet.
  - presence of more than two metallic particles or objects less than 3/8 inch per 50 pounds of cullet.
- Cullet should be free of wire, staples, nails, bolts, welding rods, and other similar objects.
- Metallic foil from bottle labels will not be considered as metallic contamination.
- Glass must be free of dirt, gravel, limestone chips, asphalt, concrete, and excessive amounts of paper, cardboard, wrap, or plastics.
- Large amounts of excessively decorated glass must be kept separate.

Source: Brockway, Inc. (in EPA, 1988)

Optical sorting first separates transparent (glass) and opaque (presumably non-glass) particles, then sorts the transparent particles by color. The particles fall one at a time past a light source and photocell, which registers the intensity of light transmitted through the particle. An electronic component of the system determines whether the particle is acceptable, based on the photocell response. If the particle is unacceptable, a small burst of air deflects it from the flow of particles into a reject bin. The system is fairly successful in separating flint from non-flint glass and in separating glass and non-glass refractory materials (EPA, 1988c). It is less efficient at separating green and amber glass. Optical sorting has not found wide application and is considered infeasible for large-scale use because the equipment is expensive. On a commercial scale, it is unable to meet the cullet specifications of the glass container industry.

Froth flotation is used to separate finely ground glass and non-glass particles. The system is based on the tendency of hydrophobic particles to float to the surface of an aqueous system. An aqueous mixture of very fine glass and non-glass particles is treated with a hydrophobic compound that selectively adheres to the glass particles. When air is blown through the mixture, the glass floats to the surface and may be skimmed off, while the non-glass particles sink to the bottom. No practical method exists to color-sort the cullet resulting from froth flotation; the particles are too fine for optical or hand sorting. Particles could be optically sorted, then ground up and froth floated, but this is not economically viable under present market conditions. Because most post-consumer glass is recycled into containers (see below), and the specifications are strict, color separation is essential. Optical sorting and froth flotation are ineffective at sorting glass by color. Community glass recycling programs unsurprisingly require hand sorting.

C.2 PRODUCTS CONTAINING RECYCLED POSTCONSUMER MATERIALS

Glass containers account for 90 percent of recycled cullet use. The two largest existing uses for the remaining 10 percent are in the manufacture of small glass beads or microspheres for use in reflective paint for road signs and in the manufacture of glass wool insulation (Papke, 1983). A variety of other uses are also possible, but not currently in common use, although glasphalt is a topic of much publicity.

C.2.1 Glass Containers

The glass industry produces about 11 million tons of glass containers each year. These containers consist, on the average, of about 20 to 25 percent cullet. About 2.5 million tons per year of cullet is used to produce glass containers, of which about 1.3 million tons is postconsumer cullet (U.S. Congress, 1989). Another source estimates about 1.1 million tons of postconsumer glass was recovered in 1986 (Franklin Associates, 1988). Consumers discarded about 12.9 million tons of glass in 1986, accounting for about 8 percent of all MSW. The estimated 1.1 to 1.3 million tons of postconsumer glass recovered in 1986 represents a recycling rate of about 10 percent (U.S. Congress, 1989).

Most glass containers are made for beverages (soft drinks, beer, wine, and liquor) and food. Beer and soft drink containers may be refillable or one-way (non-refillable). A refillable bottle is about 50 percent heavier than a one-way bottle and is designed for about ten round trips (EPA, 1988c). Until 1975, refillable bottles dominated the market, but one-way bottles took over around 1981. One-way bottles became increasingly popular as consumers increased their demand for convenience products and refillable bottles became unable to compete effectively with one-way glass bottles and aluminum and plastic containers. Refillable bottles used to be filled at small bottling plants located near every metropolitan area, but industry moved away from small plants toward larger regional plants. Since 1975, the number of bottling plants in the U.S. has dropped from 3,000 to less than 300 (EPA, 1988c). One source estimates that more than half the glass produced in the U.S. is used for products with a lifespan of less than one year.

There is a trend toward increasing the percentage of cullet in containers to around 40 percent, and it is theoretically possible to use 100 percent cullet in glass making (EPA, 1988c). But two important barriers to increased cullet use are quantity and quality. Glass manufacturers prefer a stable supply of high-quality cullet to achieve high percentages of cullet usage. It is not feasible to operate a furnace at 20 percent cullet one week and 50 percent the next, and they would need to stockpile cullet to even the flow. Therefore, one realistic influence on cullet use is the amount that can be supplied on a regular basis.

Cullet quality also is a crucial issue and perhaps the most important one. Glass manufacturers fear "foreign" cullet (i.e., not home scrap) because its composition is less well known. Industry specifications for foreign cullet (shown in Table C-2) are very strict. Foreign cullet may be contaminated with metals, refractory materials, and noncontainer glass. In addition to damaging the furnace and other equipment, cullet that contains these materials may produce glass of unacceptable quality. Metals and refractory materials can cause stones in the glass, which weaken the glass and may even be visible if large enough. Noncontainer glass generally has a different chemical composition than container glass. Small quantities of flat glass in cullet are acceptable if the chemical composition is known, but it seldom is. Therefore, container manufacturers are reluctant to buy cullet known to contain noncontainer glass. Foreign cullet also may contain glass of another color. This can result in off-color glass, especially when the glass being produced is flint glass. (Amber glass is less sensitive to mixed colored cullet, and green glass is fairly insensitive.) Consumers generally will not tolerate color variations in glass containers, so glass manufacutrers will use post-consumer cullet only if they are confident they can get reliably high-quality cullet. Therefore, improved collection and beneficiation processes are necessary to increase the percentage of postconsumer cullet used by glass manufacturers (U.S. Congress, 1989).

Some glass plants have their own beneficiation facilities. These facilities grind the glass, remove metals, and clean the cullet. There were 25 of these facilities in the U.S. in April 1988, and 3 more were expected to be operational by the end of 1988. Such facilities cost $500,000 to $1 million to build. As more glass is recycled, more of these facilities are expected to be built to ensure consistent cullet quality (U.S. Congress, 1989). While these systems are good at removing metal, they generally cannot remove all non-metal contaminants, and there is no commercially successful equipment for color-sorting crushed glass (EPA, 1988c). Some facilities use hand sorting to color sort and remove refractory materials. In general, source separation is more effective for color sorting than separation at a MRF because of container breakage at the facility (U.S. Congress, 1989).

Mixed-color cullet can be used in the manufacture of container glass to some extent. Green glass is relatively insensitive to the presence of glass of other colors in cullet. Even flint glass can tolerate some color contamination if enough pure cullet (e.g., from home scrap) is also used. Also, chemical additives counteract the effect of the pigments in green and amber glass, but the composition of the cullet must be well known to use this approach.

The market value of cullet for container manufacturers depends on the degree of color sorting and the geographic area of the country. In 1989, final market cullet prices were fairly stable, around $40 to $60 per ton of color-sorted cullet. Proximity to a high concentration of glass producers, such as in the New Jersey/Pennsylvania area, may increase the value of cullet. Also, in California, state interventions in recycling have pushed the value of cullet up as high as $132 per ton (Apotheker, 1989b).

The market for glass containers should continue to remain stable and possibly increase, despite competition from aluminum and plastic, due to the high-quality image of glass, its microwaveability, and its recyclability (U.S. Congress, 1989). Another factor in favor of increased cullet use is the increasing price of industrial sand, the primary raw virgin material in glass. These increased prices reflect higher mining costs and increasing demand (U.S. Congress, 1989).

C.2.2 Other Products

Most other products can be made from flat glass cullet as well as container glass. Flat glass may be contaminated with putty and paint (from window glass), ceramics, and headlight glass. This does not cause problems in some applications, like glasphalt, but does in others, such as fiberglass (EPA, 1988c).

C.2.2.1 Glass Beads

In 1983, manufacturers used over 50,000 tons of cullet to make small glass beads or microspheres for use in reflective paint for road signs. The manufacture of these beads uses 100 percent cullet in most cases and can use flat glass cullet as well as container glass cullet. There is an increasing market for these spheres for other applications (for example, to replace glass fiber in reinforced plastics) (Papke, 1983).

C.2.2.2 Glass Wool Insulation

Another existing use for cullet is glass wool insulation. Only one glass wool insulation manufacturer uses cullet in 1983, with cullet composing 20 to 50 percent of the inputs. The use of cullet in glass wool manufacture was expected to expand rapidly as larger, more reliable supplies of cullet became available (Papke, 1983).

C.2.2.3 Glasphalt

Glasphalt is a substitute for asphalt that uses 30 to 60 percent glass cullet in place of rock aggregate. The cullet need not be color sorted, only free of metal, plastic, and labels. Glasphalt has been shown to wear well in test strips, but there is some indication that it is only appropriate for lower speed roadways due to decreased traction at higher speeds. Glasphalt also "strips" for a short period after it is applied, leaving small pieces of glass on the surface. While this poses no threat, it is apparently disturbing to the public. The only widespread use of glasphalt has been in Baltimore, Maryland, where it is used for aesthetic purposes (it sparkles, unlike regular asphalt) in renovated areas of the city. The U.S. uses about 1 billion tons of asphalt each year, so the potential of glasphalt would seem to be great. Nevertheless, there are economic barriers to its use. The cost of rock aggregate, the raw material being replaced, is low ($2 to $6 per ton), so that glass cullet has no greater value than rock aggregate in this application. The city of Baltimore has actually found that glasphalt costs more than regular asphalt, but they have been willing to pay more for glasphalt's aesthetic properties. Even with the aesthetic qualities of glasphalt, the use of glass in glasphalt probably will not increase unless the market for use of glass in containers (where it has a much higher value) decreases (U.S. Congress, 1989).

C.2.2.4 Building and Construction Uses

Cullet can be used in a variety of construction products, such as clay brick, tile, masonry brick, glascrete, lightweight aggregate for concrete and plastics, glass-polymer composites, and foamglas. Cullet is used in crushed form in most of these applications and substitutes for rock or clay aggregate. Glass cullet can increase strength and attractiveness while decreasing weight in these products. This could potentially be a large market for cullet, but it will be limited by the same economic realities as the glasphalt market: the rock aggregate being replaced generally has a cost of only $2 to $6 per ton (Papke, 1983). One exception is the use of cullet as a fluxing agent in clay brick. In this case, it not only replaces some of the raw materials, but allows the bricks to be fired at a lower temperature, reducing energy costs (EPA, 1988c).

C.2.2.5 In-House Recycling

Industrially derived waste glass (produced largely by businesses that make, shape, or treat glass) is often recycled in-house and is known as "runaround" scrap. In-house recycling efforts separate glass by product type, rather than color. Because different types of flat glass may have significantly different chemical composition and melting properties, mixing different types could produce cullet unusable for either type (EPA, 1988c).

C.3 CURRENT AND HISTORICAL STATISTICS ON SECONDARY MATERIALS

Table C-3 shows the amount of glass discarded in MSW (after materials recovery, before energy recovery) from 1960 to 1986, with projections for 1990 to 2000. The table breaks down figures into container and noncontainer[1] glass, further breaking down container glass into beer and soft drink, wine and liquor, and food and other. In 1986, U.S. consumers discarded 11.8 million tons of glass, accounting for 8.4 percent of MSW. Glass containers accounted for 10.7 million tons (or 91 percent) of the total glass discarded and 7.6 percent of all MSW. The 11.8 million tons of glass discarded does not include 1.1 million tons of glass recovered from MSW. The 1.1 million tons recovered accounts for 8.5 percent of gross glass discards (12.9 million tons) (Franklin Associates, 1988).

[1] The noncontainer glass category includes pressed and blown glass, and flat glass, but excludes fiberglass and glass beads. No further breakdown (into types of flat or pressed and blown glass) is available. (Franklin 1988).

TABLE C-3. GLASS DISCARDED[a] TO MUNICIPAL WASTE STREAM, 1960 TO 2000[b] (MILLION TONS)

Type of Glass	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1990	1995	2000
Containers	5.9 (7.2%)	8.0 (8.3%)	11.7 (10.4%)	12.3 (10.6%)	13.2 (10.2%)	13.3 (10.1%)	12.8 (9.9%)	12.3 (9.1%)	11.7 (8.5%)	11.1 (8.1%)	10.7 (7.6%)	11.2 (7.5%)	11.0 (6.9%)	10.8 (6.4%)
Beer and soft drink	1.3	2.5	5.4	5.9	6.0	6.0	5.8	5.4	4.8	4.7	4.5	4.4	4.3	4.1
Wine and liquor	0.9	1.4	1.9	2.0	2.4	2.2	2.2	2.2	2.2	2.2	2.1	2.2	2.2	2.1
Food and other	3.4	4.2	4.4	4.4	4.8	4.8	4.8	4.7	4.7	4.3	4.1	4.6	4.5	4.5
Non-container glass	0.5 (0.6%)	0.5 (0.5%)	0.8 (0.7%)	0.9 (0.8%)	1.0 (0.8%)	1.0 (0.8%)	1.0 (0.8%)	1.0 (0.8%)	1.1 (0.8%)	1.1 (0.8%)	1.1 (0.8%)	1.1 (0.8%)	1.2 (0.8%)	1.2 (0.7%)
TOTAL	6.4 (7.8%)	8.5 (8.8%)	12.5 (11.1%)	13.2 (11.4%)	14.2 (11.0%)	14.3 (10.9%)	13.8 (10.7%)	13.3 (9.9%)	12.8 (9.3%)	12.2 (8.9%)	11.8 (8.4%)	12.3 (8.3%)	12.2 (7.7%)	12.0 (7.1%)

[a] After materials recovery, before energy recovery.
[b] Figures for 1990, 1995, and 2000 are projections.
Note: Figures in parentheses represent percent of MSW.
Source: Franklin Associates 1988.

There are no data on how much glass remains in the MSW stream after energy recovery. Glass is noncombustible and abrasive to processing equipment, and it forms a slag in the furnace (EPA, 1988c).

The amount of all glass discarded to MSW increased from 1960 to 1981, then decreased until 1986. Container glass accounted for most of this increase; noncontainer glass discards were stable between 1981 and 1986. Container glass discards were predicted to jump between 1986 and 1990, then gradually decrease until 2000. Noncontainer discards are predicted to continue to be stable until 2000. As a percentage of all MSW, container glass peaked at 10.6 percent in 1975 and is now declining. Noncontainer glass has consistently accounted for about 0.8 percent of all MSW since 1970 (Franklin Associates, 1988).

These patterns for container glass reflect the popularity of glass bottles in the 1970's and the increased competition from aluminum and plastic in the 1980's. Glass offers several qualities that should help to maintain its market share:

- high consumer acceptance,
- image of purity and prestige,
- use in microwave ovens,
- barrier properties, and
- recyclability.

A 1987 consumer survey indicated that 34 percent prefer glass bottles for soft drinks and 60 percent prefer glass bottles for beer. (By comparison, 31 and 34 percent expressed a preference for metal cans for soft drinks and beer respectively) (EPA, 1988c).

C.4 RECENT MARKET INTERVENTIONS BY FEDERAL AND STATE GOVERNMENTS

C.4.1 Beverage Container Deposit Legislation (Bottle Bills)

Bottle bill laws require the consumer to pay a deposit on beverage containers, which can be redeemed by returning the bottles to the retailer. Such laws have replaced once-common bottler-promoted deposit programs. Nine states (Connecticut, Delaware, Iowa, Maine, Massachusetts, Michigan, New York, Oregon, and Vermont) have enacted bottle bills and 23 others are considering such legislation. Decreased littering and increased awareness of recycling behavior are usually cited as the advantages of bottle bill laws. One study suggests that up to 90 percent of discarded glass containers have been diverted from the MSW waste stream by bottle bill legislation (EPA, 1988c).

Bottle bills, however, appear to have a negative effect on the glass industry. Bottle bills tend to encourage a shift from glass containers to plastic and aluminum, for two reasons: most retail outlets do not have adequate storage space on the premises to handle returned glass bottles, and consumers in states with bottle bills also seem to prefer the easier handling of lightweight plastic and aluminum. Thus, while one goal of bottle bills is to divert glass from landfills and encourage recycling, bottle bills instead encourage a market shift to less recyclable products (plastic) (EPA, 1988c). Bottle bills may encourage a shift to refillable glass bottles, as in New York in 1984, when the market share for refillables increased from 5.1 percent to 6 percent. Nevertheless, nonrefillables suffered a much greater loss of market share, from 27.9 percent to 18.9 percent (EPA, 1988c).

Another result of bottle bill legislation is that glass markets may flood, sharply decreasing the price for waste glass. Some experts say that only green glass markets flood, while flint glass markets remain stable. Regional differences in these phenomena exist; for example, West Coast states do not seem to have experienced the market flooding and container purchase shifts that states on the East Coast have (EPA, 1988c).

Bottle bill legislation removes glass, a secondary commodity for which proven recycling technologies exist, from the waste stream without significantly decreasing the solid waste stream. In addition, excluding beverage containers from a mandatory curbside collection program can have a significant cost, because glass is an important commodity for such programs (EPA, 1988c).

C.4.2 Summary of State Recycling Programs

Table C-4 summarizes current state glass recycling programs in nine states and the District of Columbia. The states included are California, Florida, Indiana, Maryland, North Carolina, Pennsylvania, South Carolina, Virginia, and Wisconsin. Most of these programs rely on public information and education to promote voluntary collection or buyback. Where statistics are available, the programs have a discernible effect. Another eight states are considering such programs: Arkansas, Colorado, Kansas, Louisiana, Montana, New Mexico, Oklahoma, and Texas.

Fourteen states[2] have enacted legislation encouraging or requiring municipalities to implement community recycling programs. Three states[3] have mandatory source separation programs.

The New Jersey law is an example of government intervention that stimulates a reliable supply of marketable cullet. New Jersey passed the Mandatory Statewide Source Separation and Recycling Act in April 1987. This law requires counties to appoint a district recycling coordinator; identify three recyclables (in addition to leaves) as designated recyclables for the district; and develop a strategy for collecting, marketing, and depositing the source-separated materials in each municipality. Counties must solicit proposals for processing and marketing recycled materials and enter into contracts on behalf of the municipalities for these activities. The law requires municipalities to appoint a local recycling director, provide a collection system, and adopt ordinances requiring generators of MSW to separate the designated recyclables at the source (EPA, 1988c). Because source separation remains one of the most effective ways to color sort glass cullet, such programs should increase not only the quantity of cullet recycled, but the quality of the cullet as well. Color-separated cullet has a much higher market value than mixed-color cullet.

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[2] Connecticut, Florida, Hawaii, Illinois, Maryland, Massachusetts, Minnesota, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Washington, and Wisconsin.

[3] Connecticut, New Jersey, and Rhode Island.

TABLE C-4. SUMMARY OF STATE GLASS RECYCLING PROGRAMS

California

- California Beverage Container Recycling and Litter Reduction Act
  - Effective September 1, 1987.
  - Guarantees consumers at least 1 cent per recycled beverage container.
  - Mandates 65 percent recycling rate.
  - Mandates establishment of certified recycling centers in each of 2000 "convenience zones" (an area within a half mile of any grocery store doing over $2 million worth of business per year).
- California Glass Recycling Corporation
  - Sponsored by the glass industry.
  - Over 500 collection banks operated statewide.
  - Public information and technical assistance programs.
  - Phoenix Program: collection from commercial establishments, such as bars and restaurants. Earning establishments $20/ton.

Florida

- Florida Glass Recycling Program
  - Established spring 1986.
  - Supported by glass industry.
  - Educational programs directed at school children to promote voluntary recycling.
  - Theme-related recycling centers; Goodwill Industries opened one with an agricultural theme and collected 2 million tons of glass in one year. Goodwill plans 15 more theme-related centers statewide.
- Florida Business and Industry Recycling Program
  - Statistics show increase of 19 percent in glass collections in 1986.
  - Brought about by 57 recycling organizations.
  - Florida glass plants bought 53.5 million pounds of postconsumer glass containers in 1986 (up from 45 million pounds in 1985).
  - Revenues to recyclers for collected glass in 1986 estimated at $1.6 million.

Indiana

- Indiana Glass Recycling Association
  - Established summer 1987.
  - Backed by five major glass manufacturers in the state.
  - Use educational and promotional materials to increase number of recycling centers that accept glass.
  - Distributes the "Great Glass Caper" school curriculum to fourth-grade classes. The curriculum explains the basics of glass recycling to promote interest and participation in future consumers.

continued

TABLE C-4. SUMMARY OF STATE GLASS RECYCLING PROGRAMS (CONTINUED)

Maryland, Virginia, District of Columbia

- Mid-Atlantic Glass Recycling Program
  - Established in 1987.
  - Goal is to increase public awareness and participation in existing glass recycling activities.
  - Maryland: 13 buyback centers, 32 voluntary drop-off locations, pilot curbside collection program in Anne Arundel County. State legislation mandates municipal solid waste reduction through source separation and recycling.
  - Virginia: 29 buyback centers, 19 voluntary drop-off locations in 1987.
  - Washington, DC: Operation Igloo—Glass Recycling. Places glass drop-off sites at local churches, revenues benefit host churches.

North Carolina, South Carolina

- Carolina Glass Recycling Program
  - Established June 1986.
  - In 1986 only 9 recyclers in both states accepted recycled glass.
  - Established glass recycling network of 65 organizations in 1987.
  - In 1986, about 1 million glass containers recycled per month. In 1987, up to 8 million.

Pennsylvania

- Pennsylvania Glass Recycling Corporation (PGRC)
  - Established in late 1985.
  - Pennsylvania has 2nd largest number of glass manufacturing plants in U.S. (behind California); ready market and skyrocketing waste disposal costs led to establishment of PGRC.
  - Delaware County, May 1987, placed Igloo containers at 22 sites. By December 1987, 82 tons of cullet were collected. By spring 1988, 48 Igloos placed.
  - Theme-based recycling center operated by Goodwill in Harrisburg.
  - Buyback centers encouraged; one collected the equivalent of 1.1 million 12-ounce bottles from summer 1986 to winter 1987.
  - Involved in bringing a glass processing facility to Chester, Pennsylvania, where glass is cleaned, crushed, and checked for contaminants.

Wisconsin

- Wisconsin Glass Recycling Program
  - Established April 1987.
  - Established a cooperative agreement between glass manufacturing plants and recycling organizations to guarantee market for recycled glass.
  - Existing recycling centers encouraged to accept glass.
  - "Great Glass Caper" curriculum distributed throughout the state.

APPENDIX D
ALUMINUM INDUSTRY PROFILE

The primary aluminum industry produces aluminum alloys in three basic categories: wrought alloys, casting alloys, and extrusion alloys (Alter and Reeves, 1975). Each category comprises a variety of different alloys, defined by the percentage of non-aluminum elements such as silicon, iron, manganese, magnesium, copper, titanium, zinc, and chromium. For example, in 1975 there were 150 registered wrought alloys and 75 registered casting alloys (Alter and Reeves, 1975). Small differences in an alloy's composition can affect its properties significantly, and specific alloys may be patented. Aluminum alloys are produced in a variety of forms, including ingot, sheet, billet, hot metal, notched bar, and shot (JACA, 1977a). In 1989, the primary aluminum industry produced about 4.4 million tons of aluminum. U.S. manufacturers imported another 1.7 million tons, primarily from Canada (U.S. Bureau of Mines, 1989). Table D-1 shows primary production and import levels for aluminum for 1985 through 1989.

TABLE D-1. ALUMINUM PRODUCTION, IMPORTS, AND EXPORTS, 1985 TO 1989 (MILLIONS OF TONS)

	1985	1986	1987	1988	1989
Production					
Primary	3.9	3.3	3.7	4.3	4.4
Secondary	0.9	0.9	0.9	1.1	1.2
Total	4.8	4.2	4.6	5.5	5.6
Imports	1.6	2.2	2.0	1.8	1.7
Exports	1.0	0.8	1.0	1.4	1.7
Apparent Consumption[a]	5.7	5.7	6.0	5.9	5.6

[a]Apparent consumption = primary production + secondary production + net import reliance. Net import reliance includes an adjustment for Government and industry stock changes.

Source: U.S. Bureau of Mines, 1989.

Manufacturers use primary aluminum to produce a wide variety of products in the following major categories:

- packaging,
- transportation,
- building and construction,
- electrical,
- consumer durables, and
- other.

Packaging consumes 31 percent of domestic production and includes food and beverage cans, semi-rigid foil containers, and aluminum foil. Transportation uses consume 24 percent of domestic production and includes parts for automobiles and aircraft. Building and construction claims 20 percent of production for products like aluminum siding. Electrical accounts for 10 percent of consumption and includes aluminum wire. Consumer durables account for 9 percent of consumption for products like appliances. Finally, other uses consume 6 percent of domestic production for products like lawn furniture (U.S. Bureau of Mines, 1989; all figures 1989).

Packaging in general and used beverage cans in particular account for most of the aluminum in municipal solid waste (MSW); in 1988 used beverage cans accounted for 76 to 79 percent of all aluminum in MSW. Other packaging, appliances, and lawn furniture accounted for the remainder (U.S. Congress, 1989). Aluminum from the other product types listed above is fairly uncommon in MSW; therefore, this profile will focus on packaging products.

Within the aluminum packaging sector, 82 percent of shipments in 1988 (about 1.8 million tons) were used to manufacture can sheet for beverage and food cans. The rest was used to produce foil for semi-rigid containers, packaging, and consumer use (U.S. Congress, 1989).

D.1 RAW MATERIALS

Primary aluminum is produced from bauxite, an ore containing 30 to 50 percent hydrated aluminum oxide (JACA, 1977a). Dissolving the bauxite in a strong alkali solution produces alumina, which is an important intermediate in aluminum production. Next, a procedure called smelting is used to process the alumina into aluminum. In the smelting process, the alumina is dissolved in a molten bath of cryolite, which is a sodium-aluminum-fluoride compound, and then converted to 99.7 percent pure aluminum by electrolysis with an anode paste of petroleum coke and coal tar pitch. The pure aluminum is then alloyed with various other elements to produce aluminum alloy. The procedure requires about four to five pounds of bauxite to make two pounds of alumina, which make about one pound of aluminum (JACA, 1977a).

The U.S. relies heavily on imports for the raw materials to produce aluminum. In 1989, only three companies in the U.S. owned bauxite mines, with a combined production of about 0.7 million tons. By comparison, the U.S. imported 13.9 million tons of bauxite (primarily from Guinea, Jamaica, and Australia). The U.S. produced about 5.6 million tons of alumina from domestic and imported bauxite, while importing 4.7 million tons of alumina (primarily from Australia) (U.S. Bureau of Mines, 1989). Although substitutes do exist for bauxite in the production of alumina (clay, alunite, anorthosite, coal wastes, and oil shale), none are economically feasible on a commercial scale (U.S. Bureau of Mines, 1989; JACA, 1977a).

Although bauxite has no economic substitute in the production of alumina, scrap aluminum is a readily available, highly economic substitute for alumina. Scrap aluminum can be melted down and alloyed to produce secondary aluminum, which is indistinguishable from primary aluminum. [Aluminum is referred to as primary or secondary to identify the process by which it was made (U.S. Congress, 1989)]. Using domestic aluminum scrap reduces U.S. dependence on foreign virgin materials for aluminum production (Alcoa, 1989a through 1989e). Table D-1 shows secondary aluminum production from 1985 through 1989.

Using aluminum scrap to produce aluminum also offers several other economic benefits. Primary aluminum production is an energy- and capital-intensive process. Electricity can account for up to half the cost of producing primary aluminum from alumina. Using scrap aluminum to make primary aluminum saves about 90 to 95 percent of the energy costs, or about 7.5 kwh per pound of aluminum (Alcoa, 1989a through 1989e). In addition, energy is required to mine, beneficiate, and transport raw materials for production of aluminum from alumina. Transporting foreign raw materials to the U.S. costs between $3 and $18 per ton (U.S. Congress, 1989). Clearly, using scrap aluminum results in significant energy cost savings, as well as capital cost savings. A facility to melt scrap aluminum and produce secondary aluminum takes about half the time to build and costs about one-tenth that of a primary aluminum production facility of the same size (Alcoa, 1989a through 1989e). The average world cost to build a new primary aluminum plant is $2,700 to $3,600 per ton of capacity. By comparison, the cost of three new secondary plants currently being built in the U.S. is $123 to $417 per ton of capacity (U.S. Congress, 1989; *Solid Waste Report*, 1989).

Purchased aluminum scrap is generally divided into two categories: new scrap and old scrap. New scrap consists of industrial scrap such as clippings, forgings, borings, turnings, drosses, and skimmings. Old scrap consists of discarded consumer products and also may be called postconsumer scrap (Kusik and Kenahan, 1978). Because this report focuses on the recovery of materials from MSW, this profile focuses on old or postconsumer scrap.

D.1.1 Recovery of Aluminum from MSW

Packaging comprises most of the aluminum in MSW, with lawn furniture and appliances accounting for the rest (U.S. Congress, 1989). EPA specifications for aluminum recovery from MSW recommend recovering two fractions: aluminum cans and foil and miscellaneous extrusions, castings, etc. (Alter and Reeves, 1975). The specifications for the can and foil fraction (the more valuable of the two) are as follows:

- 100 percent retained on a 12 mesh screen
- Free of heavy media
- Dried before shipment
- Not obviously corroded
- Appropriate alloy composition

Methods for processing MSW to recover aluminum include source separation, heavy media separation, eddy current separation, and electrostatic separation. In addition to these processes, a magnetic sorter is used to remove steel and other ferrous (i.e., magnetic) metals.

Source separation is the simplest way to remove aluminum from MSW. Residents separate aluminum and take it to a recycling center or to a drop-off area, where they may receive about 26 cents per pound. Or aluminum may be picked up by curbside recycling programs. Most aluminum recycling centers only accept beverage cans (by far the largest source of aluminum in MSW), although some accept other aluminum packaging and lawn furniture. Steel cans are removed by magnetic sorter (Siberg, 1982). Source-separated aluminum contains steel cans, but this contaminant is easily removed. Where the contamination is greater, as in one-stream and two-stream recycling programs, the removal of contaminants is more sophisticated.

Heavy media separation uses differences in specific gravity to separate aluminum from other materials in MSW. The materials to be separated are placed in a liquid with a specific gravity greater than some materials and less than others so that some materials sink and some float. Aluminum is separated from other MSW through three steps: (1) water (specific gravity = 1) to clean and remove very light materials; (2) ethylene dibromide (specific gravity = 2) to remove organic materials; and (3) one of several liquids with a specific gravity around 2.8 in which aluminum, some glass, and some stones float and all other MSW sinks. The float from the last step is crushed to break up glass and stones, then screened to isolate the aluminum (Siberg, 1982).

Eddy current separation removes non-ferrous metals (primarily aluminum, but also some copper and zinc). Generally, paper, light plastics, ferrous metals, glass, ceramics, dirt, and food waste have already been removed prior to eddy current separation, leaving a mixture of non-ferrous metal, wood, cardboard, heavy plastic, rubber, and rags. These are ground to a uniform particle size and moved down a slide through a magnetic, or eddy current, field. Because non-ferrous metals are electrical conductors they are affected by the field and deflected to one side, where they can be captured separately. Eddy current separation generally removes about 70 percent of the non-ferrous metal in a sample and produces a product that is greater than 90 percent pure non-ferrous metals. An eddy current separator can process about three tons of waste per hour per meter of slide width (Siberg, 1982; Schloemann, 1982).

In electrostatic separation, particles of nonferrous metal, wood, etc. are dried and placed in a grounded drum equipped with an electrode. Particles receive a positive charge and adhere to the drum. Electrical conductors (i.e., non-ferrous metals) quickly lose the charge, drop off, and are collected. Remaining material is scraped off the drum and rejected. The output of this process may include some copper, zinc, and iron, as well as aluminum (Siberg, 1982).

D.2 PRODUCTS CONTAINING RECYCLED POSTCONSUMER MATERIALS

The aluminum beverage can is by far the largest component of aluminum in MSW, and by the same token it is the dominant product of recycled aluminum. Recyclers generally return used beverage cans directly to can sheet manufacturers to be made into more cans. Other forms of reclaimed aluminum are generally used to make secondary aluminum, which can be used to make virtually any product that can be made from primary aluminum. The U.S. also exports aluminum scrap and secondary aluminum, primarily to Japan and Mexico.

D.2.1 Beverage and Food Cans

In 1988, manufacturers shipped 78 billion aluminum beverage cans to retailers; consumers returned 54.6 percent of these (43.5 billion cans) for recycling (for 0.8 million tons of aluminum). Used beverage cans account for 76 to 79 percent of the aluminum in MSW, and the aluminum recovered from MSW comes almost entirely from used beverage cans. Can sheet manufacturers used 93 percent of the used beverage cans recovered from MSW in 1988 to make new can sheet (U.S. Congress, 1989).

The aluminum beverage can was introduced in 1963. In 1964 it claimed 2 percent of the market share of canned beverages; in 1989 it held 96 percent of the canned beverage market (99.9 percent of canned beer and 93 percent of canned soft drinks). Bimetal steel cans (steel body, aluminum end) hold the remainder of the canned beverage market (Alcoa, 1989a through 1989e). In the entire beverage container market in 1988, aluminum cans had a 50 percent market share. The remaining 50 percent was divided among glass (25 percent), plastic (20 percent), and steel (5 percent) (U.S. Congress, 1989). Market share growth for aluminum cans is expected to slow, partly due to capacity restraints on the production of can stock and partly due to increased competition from plastic. The amount of competition from plastic containers will depend on manufacturers' success in increasing the recyclability of plastic (U.S. Congress, 1989; *Phoenix Quarterly*). Demand for aluminum beverage cans is expected to remain strong; aluminum is a cost-effective packaging material that chills quickly, preserves flavor, and is light, strong, unbreakable, and stackable (Alcoa, 1989a through 1989e; U.S. Congress, 1989).

Aluminum can sheet also is used to make food cans, although aluminum has not penetrated the food can market to the extent it has the beverage can market. Aluminum food cans account for about 10 percent of the 28 million food cans shipped in 1989. Food products commonly packed in aluminum cans include seafoods, meats, snacks, pudding, soups, fruits, vegetables, and pet foods. The advantages of aluminum food cans include convenience, product compatibility, stackability, recyclability, strength, dent resistance, and competitive cost. As a result of these factors, aluminum is expected to gain an increasing market share of the food can market (Alcoa, 1989a through 1989e).

Used beverage cans enjoy a very stable market in the manufacture of new can sheet. Using scrap aluminum as a substitute for virgin materials has strong economic incentives (as discussed previously) to produce aluminum products, especially when the composition of the scrap is well known, as it is for scrap from used beverage cans. Therefore, aluminum can sheet manufacturers virtually always buy aluminum can scrap (Alcoa, 1989a through 1989e).

D.2.2 Other Secondary Aluminum Products

Reclaimed aluminum that is not used directly by can sheet manufacturers is used by secondary smelters to make secondary aluminum. About 90 percent of secondary aluminum is made into casting alloys; of these, about 60 percent are die-casting alloys. These alloys are used mainly by the automobile and machinery industries (JACA, 1977a). Used beverage cans are not the best components for these alloys due to high cost and high manganese and magnesium content (*Phoenix Quarterly*). Secondary aluminum also may be used to make wrought alloys or as a deoxidizer in steel making (Kusik and Kenahan, 1978).

D.2.3 Exports

In 1988 the U.S. exported 536.4 thousand tons of aluminum scrap, consisting of 434.7 thousand tons of aluminum waste and scrap, 4.3 thousand tons of used beverage cans, and 97.4 thousand tons of remelt scrap ingot (*Phoenix Quarterly*). Japan is the largest recipient of this exported aluminum scrap, using it to manufacture can sheet, as a deoxidizer in steel mills, and for engine and other auto parts in the automobile industry (Furukawa, 1985).

D.3 CURRENT AND HISTORICAL STATISTICS ON SECONDARY MATERIALS

In 1989, about 1.1 million tons of postconsumer scrap aluminum was recovered, accounting for about 20 percent of apparent consumption of aluminum (U.S. Bureau of Mines, 1989).

Aluminum comprises only about one percent of MSW by weight because it is so light; however, aluminum is probably the most valuable commodity recoverable from MSW. About 76 to 79 percent of the aluminum in MSW is used beverage cans; other packaging, appliances, and lawn furniture account for the rest. In 1986, consumers discarded 2.4 million tons of aluminum, of which 1.3 million tons were used beverage cans, 0.4 million tons were other aluminum packaging, and the remainder (0.7 million tons) was non-packaging aluminum. Of the 2.4 million tons of aluminum discarded as MSW, 0.6 million tons were recovered (consisting almost entirely of used beverage cans), for an overall recovery rate of 25 percent of all aluminum discarded, 35.3 percent of aluminum packaging, and 46.2 percent of beverage cans (EPA, 1988a). Table D-2 shows trends in aluminum discarded to MSW (after materials recovery) from 1960 through 1986, with projections through 2000. The trend toward increasing aluminum discards is expected to continue.

As discussed previously, used beverage cans are the dominant variety of aluminum in MSW and account for nearly all aluminum recycled. Table D-3 shows trends in used beverage can recycling from 1985 to 1988; Figure D-1 shows those trends graphically from 1976 to 1988 (Note that these data come from two different sources, so the figures do not agree exactly.) Except for a slight dip in 1986, the used beverage can recycling rate has increased steadily since 1976. The potential exists for still higher recycling rates for used beverage cans; in California,

TABLE D-2. ALUMINUM DISCARDED TO MUNICIPAL WASTE STREAM, 1960 TO 2000[a] (MILLION TONS)

Type of Aluminum	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1990	1995	2000
Packaging	0.2 -0.20%	0.3 -0.30%	0.6 -0.50%	0.6 -0.50%	0.9 -0.70%	0.8 -0.60%	0.8 -0.60%	0.9 -0.70%	0.9 -0.70%	1 -0.70%	1 -0.70%	1.1 -0.70%	1.4 -0.90%	1.5 -0.90%
Beer and soft drink	0.1 -0.10%	0.1 -0.10%	0.3 -0.30%	0.4 -0.30%	0.6 -0.50%	0.5 -0.40%	0.5 -0.40%	0.5 -0.40%	0.6 -0.40%	0.6 -0.40%	0.7 -0.50%	0.7 -0.50%	0.8 -0.50%	1 -0.60%
Other cans	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0.1 -0.10%	0.1 -0.10%
Foil and closures	0.1 -0.10%	0.2 -0.20%	0.2 -0.20%	0.2 -0.20%	0.3 -0.20%	0.3 -0.20%	0.3 -0.20%	0.3 -0.20%	0.3 -0.20%	0.3 -0.20%	0.3 -0.20%	0.4 -0.30%	0.4 -0.30%	0.5 -0.30%
Non-packaging	0.2 -0.30%	0.2 -0.20%	0.2 -0.20%	0.4 -0.40%	0.5 -0.40%	0.6 -0.50%	0.5 -0.40%	0.6 -0.40%	0.6 -0.40%	0.6 -0.50%	0.7 -0.50%	0.9 -0.60%	1 -0.60%	1.2 -0.70%
TOTAL	0.4 -0.50%	0.5 -0.50%	0.8 -0.70%	1 -0.90%	1.4 -1.10%	1.4 -1.10%	1.3 -1.00%	1.5 -1.10%	1.5 -1.10%	1.6 -1.20%	1.7 -1.20%	2 -1.30%	2.4 -1.50%	2.7 -1.60%

[a]Figures for 1990, 1995, and 2000 are projections.
Source: Franklin Associates, 1988

TABLE D-3. USED BEVERAGE CANS SHIPPED AND RECYCLED, 1985 TO 1988

Year	Cans Shipped (billions)	Cans Reclaimed (billions)	Recycling Rate (percent)	Cans per Pound	UBC Reclaimed (millions of tons)
1985	64.9	32.8	50.5	26.6	0.6
1986	68.3	32.2	47.1	27.0	0.6
1987	72.5	36.6	50.5	27.4	0.7
1988	77.9	42.5	54.6	28.3	0.8

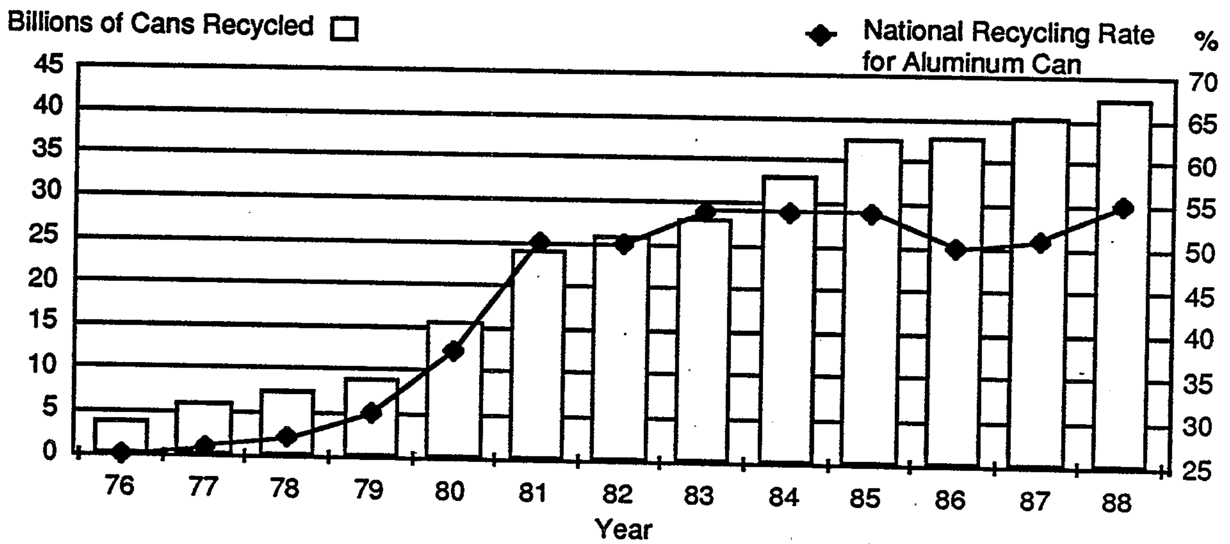

Figure D-1. Aluminum Beverage Can Recycling Growth in the U.S.
Source: Alcoa, 1989a through 1989e, *Rigid Container Sheet.*

Texas, and some Southern states, the recycling rate for used beverage cans is as high as 60 to 70 percent (Alcoa, 1989a through 1989e). The aluminum industry wants to increase the national recycling rate for used beverage cans to 75 percent by 1995 (*Phoenix Quarterly*).

Most aluminum recycling occurs through private collection efforts. In 1989, there were nearly 10,000 aluminum recycling centers in the U.S. One industry source estimates that over 10 million people regularly recycle aluminum (Alcoa, 1989a through 1989e). The primary incentive for recycling aluminum is to earn money; aluminum recycling centers pay about 26 cents per pound (about a penny a can) for used beverage cans. In 1989, recyclers earned an estimated $900 million from recycling aluminum, compared to $90 million in 1980 (Alcoa, 1989a through 1989e).

The outlook for aluminum recycling is excellent. Annual production of aluminum beverage cans is expected to continue to grow, reaching 120 billion cans by 1995. The market for recycled aluminum is strong and stable, and consumers have a financial incentive to recycle. The growth in recycling rates seen over the last decade should continue.

D.4 RECENT MARKET INTERVENTIONS BY FEDERAL AND STATE GOVERNMENTS

Aluminum recycling is unusual in that it is dominated by private collection efforts. The literature offers little information on government interventions affecting the aluminum market; however, two types of program could have some effect.

D.4.1 Mandated Source-Separation Programs

New Jersey passed a mandatory curbside recycling law in 1987 that requires counties to identify three recyclables for curbside collection. The aim is to reduce solid waste by 25 percent in two years and increase voluntary recycling (Alcoa, 1989a through 1989e). Consumers who already recycle aluminum via private buy-back centers are likely to continue to do so (because they would not get paid for aluminum recycled by the curbside program). Curbside collection could encourage aluminum recycling by other consumers who do not currently do so. Therefore, mandatory source-separation programs may increase aluminum recycling.

D.4.2 Beverage Container Deposit Legislation (Bottle Bills)

Bottle bill laws require the consumer to pay a deposit on beverage containers, which can be redeemed by returning the containers to the retailer. Nine states (Connecticut, Delaware, Iowa, Maine, Massachusetts, Michigan, New York, Oregon, and Vermont) have enacted bottle bills, and 23 others are considering such legislation. Bottle bills tend to cause a shift away from glass toward plastic and aluminum in the beverage container market (EPA, 1988c). Therefore, bottle bills could increase the availability of aluminum for recycling. It is not clear exactly what effect such legislation would have on aluminum recycling practices.

APPENDIX E

COSTS AND CREDITS OF THE MATERIALS SEPARATION REQUIREMENT FOR SELECTED GROUPS OF COMBUSTORS

The tables in Appendix E compare the costs and credits of the materials separation requirement for many different groups of combustors. To ease comparison, the tables have the same format. Each table gives the identified costs and credits of the modeled materials separation programs. The costs are the costs of collecting recyclables, while the credits are the avoided landfill cost, avoided refuse collection cost, combustor downsizing credits, and revenue from the sale of recyclable materials. The difference after the credits are subtracted from the costs is given as the total cost. This total cost is also reported per-metric-ton separated and per-metric-ton combusted. Except as noted below, the tables exclude the District of Columbia and certain states because they have laws that require at least 25 percent materials separation (see Section 2.2).

The tables are divided into eight groups. The first two groups give the costs and credits for each model program. Group 1 gives costs and credits by program type for planned combustors (regulated under the New Source Performance Standards); group two gives costs and credits for existing combustors by program type (regulated under the Emission Guidelines). Because there are many programs, and hence many tables in these groups, each group has a matrix showing which table applies to which community and program (Figures E-1 and E-2). The row at the top of each figure shows the combinations of community population and population density. The column at the left of each figure shows the three program possibilities; two-stream option 1, two-stream option 2, and multiple stream. The intersection of the column and row gives a letter that corresponds to the table with that combination of community and program.

The next two groups of tables include only one table each. Table E-3A gives the aggregate national costs and credits for all planned combustors, while Table E-4A gives the aggregate national costs and credits for all exiting combustors.

The fifth group of tables (E-5A through E-5F) gives national costs and credits for each material that would be separated under the requirement. There are six materials: newspapers, glass, plastic, aluminum, ferrous metal, and yard wastes. Figure E-3 lists each material and its corresponding table. The allocation of costs and credits to each material was accomplished by proration on the basis of weight, with one exception. The exception is yard waste. The collection and processing of yard waste occurs separately from the collection and processing of the other materials; therefore, the cost reported for yard waste is the cost of collecting yard waste and composting. The reported costs for newspapers and containers cannot be used to determine the incremental cost of collecting and processing one type of material. For all materials, credits for downsizing, avoided garbage collection, and avoided landfilling are prorated by weight.

The sixth, seventh, and eighth groups of tables give the national totals for various subgroups of combustors. Each group consists of one table. Table E-6A gives the aggregate national costs and credits for all combustors with a capacity at least 35 MgPD (megagrams per day) for all states. Table E-7A gives the national totals (excluding the nine states and the District of Columbia) that have a 100 MgPD capacity or greater. Table E-8A gives the national totals (excluding the nine states and District of Columbia) for combustors with a 35 MgPD cutoff and with a different assumption regarding composting programs. In the previous seven groups of tables, the net cost of composting reflects the assumption that some communities will not operate composting programs, some will operate backyard composting programs, and some will operate centralized composting programs. In Table 8, it is assumed that all communities operate centralized composting programs, and, consequently, the estimates of composting cost and the magnitude of credits increase.

	Community[a]						
	A (VS/L)	B (VS/M)	C (S/L)	D (S/M)	E (M/M)	F (H/M)	G (H/H)
Two Stream, Option 1				E-1A		E-1F	E-1I
Two Stream, Option 2				E-1B	E-1D	E-1G	E-1J
Multiple Stream				E-1C	E-1E	E-1H	

[a]Communities classified as follows:

Population:

VS (very small)	P ≤ 20,000
S (small)	20,001 ≤ P ≤ 100,000
M (medium)	100,000 ≤ P ≤ 200,000
H (high)	200,001 ≤ P

Density (persons/square mile):

L (low)	D ≤ 400
M (medium)	401 ≤ D ≤ 800
H (high)	801 ≤ D

FIGURE E-1. GUIDE TO TABLES IN GROUP 1 (COSTS AND CREDITS BY PROGRAM FOR PLANNED COMBUSTORS)

TABLE E-1A. MATERIALS SEPARATION COSTS SMALL POPULATION, MEDIUM DENSITY COMMUNITY TWO-STREAM RECYCLING PROGRAM: OPTION 1 PLANNED MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	13.9	15.3
Combustor Downsizing	(7.4)	(7.4)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(2.1)	(0.7)
Materials Sales Revenues	(5)	(1.6)
Total	(0.6)	5.6
$ per Mg Collected	(6.3)	58.5
$ per Mg Combusted	(1)	9.2

TABLE E-1B. MATERIALS SEPARATION COSTS SMALL POPULATION, MEDIUM DENSITY COMMUNITY TWO-STREAM RECYCLING PROGRAM: OPTION 2 PLANNED MWCS

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	4.5	4.9
Combustor Downsizing	(2.3)	(2.3)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(0.6)	(0.2)
Materials Sales Revenues	(1.8)	(0.6)
Total	(0.2)	1.8
$ per Mg Collected	(10.1)	57
$ per Mg Combusted	(1.7)	9.6

TABLE E-1C. MATERIALS SEPARATION COSTS SMALL POPULATION, MEDIUM DENSITY COMMUNITY MULTIPLE STREAM RECYCLING PROGRAM PLANNED MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	8.4	9.1
Combustor Downsizing	(4.2)	(4.2)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(1.1)	(0.3)
Revenues	(2.7)	(0.9)
Total	0.4	3.7
$ per Mg Collected	8.1	74.9
$ per Mg Combusted	1.3	11.8

TABLE E-1D. MATERIALS SEPARATION COSTS MEDIUM POPULATION, MEDIUM DENSITY COMMUNITY TWO-STREAM RECYCLING PROGRAM: OPTION 2 PLANNED MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	1.1	1.3
Combustor Downsizing	(0.6)	(0.6)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(0.2)	(0.3)
Materials Separation Revenues	(0.6)	(0.1)
Total	(0.3)	0.3
$ per Mg Collected	(21.5)	45.4
$ per Mg Combusted	(3.5)	7.4

TABLE E-1E. MATERIALS SEPARATION COSTS
MEDIUM POPULATION, MEDIUM DENSITY COMMUNITY
MULTIPLE STREAM RECYCLING PROGRAM
PLANNED MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	2.5	2.8
Combustor Downsizing	(1.1)	(1.1)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(0.4)	(0.1)
Materials Separation Revenues	(0.9)	(0.3)
Total	0.1	1.4
$ per Mg Collected	4.8	70.6
$ per Mg Combusted	0.7	10.3

TABLE E-1F. MATERIALS SEPARATION COSTS
HIGH POPULATION, MEDIUM DENSITY COMMUNITY
TWO-STREAM RECYCLING PROGRAM: OPTION 1
PLANNED MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	40.9	48.2
Combustor Downsizing	(19.7)	(19.7)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(10.3)	(2.5)
Materials Separation Revenues	(21.1)	(6.7)
Total	(10)	19
$ per Mg Collected	(22.6)	43.1
$ per Mg Combusted	(3.3)	6.3

TABLE E-1G. MATERIALS SEPARATION COSTS HIGH POPULATION, MEDIUM DENSITY COMMUNITY TWO-STREAM RECYCLING PROGRAM: OPTION 2 PLANNED MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	9	11
Combustor Downsizing	(3)	(3)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(2)	(0.5)
Materials Separation Revenues	(5)	(2)
Total	(0.9)	6
$ per Mg Collected	(9.1)	57.7
$ per Mg Combusted	(1.5)	9.5

TABLE E-1H. MATERIALS SEPARATION COSTS HIGH POPULATION, MEDIUM DENSITY COMMUNITY MULTIPLE STREAM RECYCLING PROGRAM PLANNED MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	13	14.8
Combustor Downsizing	(4)	(4)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(2.6)	(0.6)
Materials Separation Revenues	(5.3)	(2.6)
Total	1	9
$ per Mg Collected	10.9	76.5
$ per Mg Combusted	1.6	11.2

**TABLE E-1I. MATERIALS SEPARATION COSTS
HIGH POPULATION, HIGH DENSITY COMMUNITY
TWO-STREAM RECYCLING PROGRAM: OPTION 1
PLANNED MWCs**

	Estimate One	Estimate Two
(Annualized Cost in 10^6)		
Total Separation	80.7	66.8
Combustor Downsizing	(36)	(36)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(22.6)	(5.4)
Materials Separation Revenues	(37.8)	(12)
Total	(15.7)	13.4
$ per Mg Collected	(17)	47.4
$ per Mg Combusted	(2.3)	6.4

**TABLE E-1J. MATERIALS SEPARATION COSTS
HIGH POPULATION, HIGH DENSITY COMMUNITY
TWO-STREAM RECYCLING PROGRAM: OPTION 2
PLANNED MWCs**

	Estimate One	Estimate Two
(Annualized Cost in 10^6)		
Total Separation	34	39.7
Combustor Downsizing	(13)	(13)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(8.1)	(1.9)
Materials Separation Revenues	(19.6)	(6.2)
Total	(7)	19
$ per Mg Collected	(17.2)	49.6
$ per Mg Combusted	(2.7)	7.8

	Community[a]						
	A (VS/L)	B (VS/M)	C (S/L)	D (S/M)	E (M/M)	F (H/M)	G (H/H)
Two Stream, Option 1				E-2E	E-2G	E-2J	E-2M
Two Stream, Option 2	E-2A		E-2C	E-2F	E-2H	E-2K	E-2N
Multiple Stream	E-2B		E-2D		E-2I	E-2L	

[a]Communities classified as follows:

Population:

VS (very small)	P ≤ 20,000
S (small)	20,001 ≤ P ≤ 100,000
M (medium)	100,000 ≤ P ≤ 200,000
H (high)	200,001 ≤ P

Density (persons/square mile):

L (low)	D ≤ 400
M (medium)	401 ≤ D ≤ 800
H (high)	801 ≤ D

FIGURE E-2. GUIDE TO TABLES IN GROUP 2 (COSTS AND CREDITS BY PROGRAM FOR EXISTING COMBUSTORS

TABLE E-2A. MATERIALS SEPARATION COSTS
VERY SMALL POPULATION, LOW DENSITY COMMUNITY
TWO-STREAM RECYCLING PROGRAM: OPTION 2
EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	0.5	0.5
Combustor Downsizing	NA	NA
Avoided Landfilling	(0.08)	(0.04)
Avoided Garbage Collection	(0.03)	(0.02)
Materials Separation Revenues	(0.1)	(0.3)
Total	0.29	0.14
$ per Mg Collected	166.3	236.3
$ per Mg Combusted	34.9	49.6

TABLE E-2B. MATERIALS SEPARATION COSTS
VERY SMALL POPULATION, LOW DENSITY COMMUNITY
MULTIPLE STREAM RECYCLING PROGRAM
EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	1.4	1.4
Combustor Downsizing	NA	NA
Avoided Landfilling	(0.3)	(0.1)
Avoided Garbage Collection	(0.1)	(0.06)
Materials Separation Revenues	(0.3)	(0.09)
Total	0.8	1.15
$ per Mg Collected	139.6	210.1
$ per Mg Combusted	27	40.4

TABLE E-2C. MATERIALS SEPARATION COSTS SMALL POPULATION, LOW DENSITY COMMUNITY TWO-STREAM RECYCLING PROGRAM: OPTION 2 EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	12	13.1
Combustor Downsizing	NA	NA
Avoided Landfilling	(4)	(1.9)
Avoided Garbage Collection	(2)	(0.5)
Materials Separation Revenues	(5)	(1.5)
Total	1	8.2
$ per Mg Collected	23.4	115.3
$ per Mg Combusted	4.9	24.2

TABLE E-2D. MATERIALS SEPARATION COSTS SMALL POPULATION, LOW DENSITY COMMUNITY MULTIPLE STREAM RECYCLING PROGRAM EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	29	31.6
Combustor Downsizing	NA	NA
Avoided Landfilling	(7.3)	(3.7)
Avoided Garbage Collection	(3.5)	(1)
Materials Separation Revenues	(8.5)	(2.7)
Total	9.7	24.2
$ per Mg Collected	60.5	148.9
$ per Mg Combusted	11.7	28.8

TABLE E-2E. MATERIALS SEPARATION COSTS
SMALL POPULATION, MEDIUM DENSITY COMMUNITY
TWO-STREAM RECYCLING PROGRAM: OPTION 1
EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	3	3
Combustor Downsizing	NA	NA
Avoided Landfilling	(0.9)	(0.4)
Avoided Garbage Collection	(0.4)	(0.1)
Materials Separation Revenues	(1.0)	(0.3)
Total	0.5	2.1
$ per Mg Collected	28.3.	113.1
$ per Mg Combusted	5.4	21.6

TABLE E-2F. MATERIALS SEPARATION COSTS
SMALL POPULATION, MEDIUM DENSITY COMMUNITY
TWO-STREAM RECYCLING PROGRAM: OPTION 2
EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	2.5	2.7
Combustor Downsizing	NA	NA
Avoided Landfilling	(0.8)	(0.4)
Avoided Garbage Collection	(0.4)	(0.1)
Materials Separation Revenues	(1)	(0.3)
Total	0.3	1.9
$ per Mg Collected	18.6	109.2
$ per Mg Combusted	3.9	22.9

TABLE E-2G. MATERIALS SEPARATION COSTS
MEDIUM POPULATION, MEDIUM DENSITY COMMUNITY
TWO-STREAM RECYCLING PROGRAM: OPTION 1
EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	25.3	28.9
Combustor Downsizing	NA	NA
Avoided Landfilling	(10.3)	(5.2)
Avoided Regular Refuse	(5.2)	(1.3)
Materials Separation Revenues	(10.7)	(3.4)
Total	(0.4)	19
$ per Mg Collected	(4.5)	83.2
$ per Mg Combusted	(0.8)	14.7

TABLE E-2H. MATERIALS SEPARATION COSTS
MEDIUM POPULATION, MEDIUM DENSITY COMMUNITY
TWO-STREAM RECYCLING PROGRAM: OPTION 2
EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	8.7	9.9
Combustor Downsizing	NA	NA
Avoided Landfilling	(3.6)	(1.9)
Avoided Garbage Collection	(1.7)	(0.4)
Materials Separation Revenues	(4.4)	(1.4)
Total	(1)	6.2
$ per Mg Collected	(12.9)	76.3
$ per Mg Combusted	(2.6)	15.3

TABLE E-2I. MATERIALS SEPARATION COSTS
MEDIUM POPULATION, MEDIUM DENSITY COMMUNITY
MULTIPLE STREAM RECYCLING PROGRAM
EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	4.9	5.5
Combustor Downsizing	NA	NA
Avoided Landfilling	(1.7)	(0.8)
Avoided Garbage Collection	(0.8)	(0.2)
Materials Separation Revenues	(1.7)	(0.5)
Total	0.7	4
$ per Mg Collected	19.2	106.7
$ per Mg Combusted	3.4	18.9

TABLE E-2J. MATERIALS SEPARATION COSTS
HIGH POPULATION, MEDIUM DENSITY COMMUNITY
TWO-STREAM RECYCLING PROGRAM: OPTION 1
EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Costs of Collecting Recyclables	80.7	95
Combustor Downsizing	NA	NA
Avoided Landfilling	(40.1)	(20.5)
Avoided Garbage Collection	(20.3)	(4.9)
Materials Separation Revenues	(41.7)	(13.3)
Total	(21.4)	56.3
$ per Mg Collected	(24.3)	63.9
$ per Mg Combusted	(4.3)	11.3

TABLE E-2K. MATERIALS SEPARATION COSTS HIGH POPULATION, MEDIUM DENSITY COMMUNITY TWO-STREAM RECYCLING PROGRAM: OPTION 2 EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	24.1	28
Combustor Downsizing	NA	NA
Avoided Landfilling	(12)	(6.1)
Avoided Garbage Collection	(5.5)	(1.3)
Materials Separation Revenues	(14.4)	(4.6)
Total	(7.8)	16
$ per Mg Collected	(29.8)	60.6
$ per Mg Combusted	(6)	12.2

TABLE E-2L. MATERIALS SEPARATION COSTS HIGH POPULATION, MEDIUM DENSITY COMMUNITY MULTIPLE STREAM RECYCLING PROGRAM EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	32.9	37.5
Combustor Downsizing	NA	NA
Avoided Landfilling	(12.8)	(6.5)
Avoided Garbage Collection	(6.5)	(1.6)
Materials Separation Revenues	(13.4)	(4.2)
Total	0.2	25.2
$ per Mg Collected	0.6	89.2
$ per Mg Combusted	0.1	15.8

TABLE E-2M. MATERIALS SEPARATION COSTS HIGH POPULATION, HIGH DENSITY COMMUNITY TWO-STREAM RECYCLING PROGRAM: OPTION 1 EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in 10^6)		
Total Separation	84.9	101.8
Combustor Downsizing	NA	NA
Avoided Landfilling	(43.8)	(22.3)
Avoided Garbage Collection	(23.8)	(5.7)
Materials Separation Revenues	(39.8)	(12.6)
Total	(22.5)	61.2
$ per Mg Collected	(23.6)	64.0
$ per Mg Combusted	(3.8)	10.3

TABLE E-2N. MATERIALS SEPARATION COSTS HIGH POPULATION, HIGH DENSITY COMMUNITY TWO-STREAM RECYCLING PROGRAM: OPTION 2 EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in 10^6)		
Total Separation	46.5	54.3
Combustor Downsizing	NA	NA
Avoided Landfilling	(23.3)	(11.9)
Avoided Garbage Collection	(11.1)	(2.7)
Materials Separation Revenues	(26.8)	(8.6)
Total	(13.7)	31.1
$ per Mg Collected	(28.5)	61.1
$ per Mg Combusted	(5.5)	11.8

TABLE E-3. MATERIALS SEPARATION COSTS NATIONAL TOTALS FOR ALL PROGRAMS PLANNED MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	208	244
Combustor Downsizing	(90)	(90)
Avoided Landfilling	NA	NA
Avoided Garbage Collection	(50)	(12)
Materials Separation Revenues	(100)	(32)
Total	(32)	110
$ per Mg Collected	(15)	53
$ per Mg Combusted	(2)	7

TABLE E-4. MATERIALS SEPARATION COSTS NATIONAL TOTALS FOR ALL PROGRAMS EXISTING MWCs

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	357	413
Combustor Downsizing	NA	NA
Avoided Landfilling	(161)	(82)
Avoided Residential Refuse Collection	(81)	(20)
Materials Separation Revenues	(168)	(54)
Total	(54)	(256)
$ per Mg Collected	(15)	(73)
$ per Mg Combusted	(3)	(13)

Newspaper	E-5A
Glass	E-5B
Aluminum	E-5C
Ferrous	E-5D
Plastic	E-5E
Yard Waste	E-5F

FIGURE E-3. GUIDE TO TABLES IN GROUP 5 (COST AND CREDITS BY MATERIAL SEPARATED)

TABLE E-5A. MATERIALS SEPARATION COSTS NATIONAL AGGREGATE TOTALS BY MATERIAL NEWSPAPERS

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	184	199
Combustor Downsizing	(17)	(17)
Avoided Landfilling	(30)	(15)
Avoided Garbage Collection	(25)	(6)
Materials Sales Revenues	(47)	(6)
Total	63	154
$ per Mg Collected	11	27
$ per Mg Combusted	2	5

TABLE E-5B. MATERIALS SEPARATION COSTS NATIONAL AGGREGATE TOTALS BY MATERIAL GLASS

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	125	141
Combustor Downsizing	(11)	(11)
Avoided Landfilling	(21)	(10)
Avoided Garbage Collection	(17)	(4)
Materials Sales Revenues	(58)	(14)
Total	17	99
$ per Mg Collected	3	18
$ per Mg Combusted	0.5	3

TABLE E-5C. MATERIALS SEPARATION COSTS NATIONAL AGGREGATE TOTALS BY MATERIAL ALUMINUM

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	12	28
Combustor Downsizing	(1)	(1)
Avoided Landfilling	(2)	(1)
Avoided Garbage Collection	(1)	(4)
Materials Sales Revenues	(83)	(41)
Total	(75)	(16)
$ per Mg Collected	(13)	(3)
$ per Mg Combusted	(2)	(0.5)

TABLE E-5D. MATERIALS SEPARATION COSTS NATIONAL AGGREGATE TOTALS BY MATERIAL FERROUS METAL

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	32	47
Combustor Downsizing	(3)	(3)
Avoided Landfilling	(5)	(3)
Avoided Garbage Collection	(4)	(1)
Materials Sales Revenues	(16)	(11)
Total	4	30
$ per Mg Collected	0.6	5
$ per Mg Combusted	0.1	0.9

TABLE E-5E. MATERIALS SEPARATION COSTS NATIONAL AGGREGATE TOTALS BY MATERIAL PLASTIC

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	55	70
Combustor Downsizing	(5)	(5)
Avoided Landfilling	(10)	(5)
Avoided Garbage Collection	(7)	(2)
Materials Sales Revenues	(64)	(13)
Total	(31)	(46)
$ per Mg Collected	(6)	(8)
$ per Mg Combusted	(1)	(1)

TABLE E-5F. MATERIALS SEPARATION COSTS NATIONAL AGGREGATE TOTALS BY MATERIAL YARDWASTE

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	156	171
Combustor Downsizing	(52)	(52)
Avoided Landfilling	(92)	(47)
Avoided Garbage Collection	(75)	(18)
Materials Sales Revenues	(0)	(0)
Total	(63)	54
$ per Mg Collected	(11)	10
$ per Mg Combusted	(2)	2

TABLE E-6. MATERIALS SEPARATION COSTS
NATIONAL AGGREGATE TOTALS
COMBUSTORS WITH AT LEAST 35 MGPD CAPACITY, ALL STATES

	Estimate One	Estimate Two
(Annualized Cost in 10^6)		
Total Separation	789	915
Combustor Downsizing	(125)	(125)
Avoided Landfilling	(261)	(133)
Avoided Garbage Collection	(181)	(44)
Materials Sales Revenues	(338)	(120)
Total	(116)	492
$ per Mg Collected	(20)	62
$ per Mg Combusted	(5)	14

TABLE E-7. MATERIALS SEPARATION COSTS
NATIONAL AGGREGATE TOTALS
COMBUSTORS WITH AT LEAST 100 MGPD CAPACITY

	Estimate One	Estimate Two
(Annualized Cost in 10^6)		
Total Separation	541	631
Combustor Downsizing	(88)	(88)
Avoided Landfilling	(155)	(79)
Avoided Garbage Collection	(128)	(31)
Materials Sales Revenues	(261)	(83)
Total	(92)	342
$ per Mg Collected	(17)	63
$ per Mg Combusted	(3)	10

TABLE E-8. MATERIALS SEPARATION COSTS NATIONAL AGGREGATE TOTALS COMBUSTORS WITH AT LEAST 35 MGPD CAPACITY, ORIGINAL COMPOSTING ASSUMPTION

	Estimate One	Estimate Two
(Annualized Cost in $\$10^6$)		
Total Separation	617	709
Combustor Downsizing	(103)	(103)
Avoided Landfilling	(184)	(94)
Avoided Garbage Collection	(150)	(37)
Materials Sales Revenues	(269)	(86)
Total	(89)	390
$ per Mg Collected	(14)	60
$ per Mg Combusted	(3)	11

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

The new source performance standards and emission guidelines for municipal waste combustors mandate separation of 25 percent of municipal solid waste prior to combustion. This study investigates the residential recycling programs that communities of different populations and population densities may operate to comply with the requirement. The study predicts that two-stream and multiple-stream recycling programs, along with centralized composting, will be most frequent. The probability that a community will operate a certain program depends on the type of community and type of program. The study also predicts the relationships among the type of program, the type of community, and the diversion rates. The study calculates the total diversion of each separated material, the change in prices of these materials, the cost of each recycling program, and the national cost of the separation requirement. Cost-savings from planned combustor downsizing, avoided landfilling, and avoided garbage collection were also calculated. The estimate of net cost includes annualized capital, operations, and maintenance costs, cost-savings, and revenues.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

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