This is to certify that the

thesis entitled

Essential Factors to Enhance Growth Of
Integrated Recycling Systems for Post-Consumer
Aluminum Cans and Plastic Bottles in Japan

presented by

Tetsuya Okamoto

has been accepted towards fulfillment
of the requirements for

M.S. degree in Packaging

Susan E. Selke

Major professor

Date December 17, 1991

PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.

DATE DUE	DATE DUE	DATE DUE
AUG 0 2 1994	AUG 2 2 2001	
OCT 2 3 1995		
FEB 0 2 1998		

MSU Is An Affirmative Action/Equal Opportunity Institution

c:\circ\datedue.pm3-p.1

ESSENTIAL FACTORS TO ENHANCE GROWTH OF INTEGRATED RECYCLING SYSTEMS FOR POST-CONSUMER ALUMINUM CANS AND PLASTIC BOTTLES IN JAPAN

By

Tetsuya Okamoto

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Agriculture and Natural Resources

1991

ABSTRACT

ESSENTIAL FACTORS TO ENHANCE GROWTH OF INTEGRATED RECYCLING SYSTEMS FOR POST-CONSUMER ALUMINUM CANS AND PLASTIC BOTTLES IN JAPAN

By

Tetsuya Okamoto

This thesis aims at intensifying the development of integrated recycling programs that comprise collection, separation, processing, and marketing for post-consumer aluminum cans and plastic bottles in Japan, which is confronted by a nationwide waste crisis, by evaluating various existing types of recycling activities in the U.S.A. Primary sources of this study are research conducted by federal and State governments and industrial institutions, and articles relevant to solid waste management issued by leading publishers in the U.S.A. and Japan. In order to increase recycling rates, it is essential to encourage public participation by effecting viable education programs and providing participants with simple and convenient collection alternatives. Processing and marketing are more important for recovered plastics than for aluminum. Effective recycling systems in a community must be varied in accordance with characteristics of the community, examining effects of potential tradeoffs on each phase of the integrated recycling programs.

ACKNOWLEDGMENTS

I am deeply thankful to Susan Selke, PhD. (School of Packaging, Michigan State University), who has been the major professor of a committee for my thesis, and the other members of the committee, Jack Giacin, PhD. (School of Packaging, Michigan State University) and Charles Petty, PhD. (Chemical Engineering, Michigan State University) for all their guidance with regard to this research.

I would also like to thank the cooperation of two Japan's trading firms, Dia Packaging Corporation and Mitsubishi Corporation, from which I obtained the most about up-to-date news and specific data relevant to recycling for post-consumer aluminum cans and plastic bottles in Japan.

I am especially grateful to my wife, Yuko Okamoto, for her continuous support and inspiration in all things that I have required to get the master degree at School of Packaging.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BETC	Business Energy Tax Credit
BIRPs	Beverage Industry Recycling Programs
CPRR	The Center for Plastics Recycling Research
DEC	The Department of Environmental Conservation
EPA	The United States Environmental Protection Agency
EQBA	Environmental Quality Bond Act
FDA	The Food and Drug Administration
HDPE	High-density Polyethylene
KAB	Keep America Beautiful Systems
LDPE	Low-density Polyethylene
MITI	Ministry of International Trade and Industry (Japan)
MRRC	Material Recovery and Recycling Corporation
MSW	Municipal Solid Waste
NARI	National Association of Recycling Industries, Inc.
NSDA	National Soft Drink Association
NSWMA	National Solid Waste Management Association
PCTC	Pollution Control Tax Credits
PET	Polyethylene Terephthalate
PIDA	The Pennsylvania Industrial Development Authority
RCRA	Federal Resource Conservation and Recovery Act
RDF	Refuse-Derived Fuel
SPI	The Society of Plastics Industry
SWANA	Solid Waste Association of North America
UBC	Used Beverage Can
UPC	Universal Product Code

INTRODUCTION

It is evident that the public has been taking the problem of environmental protection more seriously year by year throughout the world. Not only environmental groups but also governments and industries have put their efforts into saving natural resources, reducing waste streams, minimizing emissions of carbon dioxide, etc. to help eliminate water and air pollution and the possibility of greenhouse effects to the greatest extent.

Under these circumstances, Japan is launching a major environmental initiative designed to meet its global responsibilities. According to government officials, the three-pronged strategy comprises massive donations for environmental programs, development of preservation technology and Japanese leadership in global forums.(JEJ,1989) A recent Nihon Keizai Shimbun (a leading economic newspaper in Japan) survey of 113 major firms showed that no fewer than 60 have recently set up, or plan to form, sections or committees specializing in the environment. These groups are designed to help their companies deal with the prospect of stricter environmental regulations at home and abroad. In addition, in an era where "green power" is spreading everywhere, they also function to shore up the corporate image and to help find business opportunities related to environmental technology and products.(JEJ,1990a)

On the other hand, in the U.S.A., municipal waste management is fast becoming a national issue of concern to all citizens. While recycling, incinerating and landfilling are three primary methods utilized to process municipal solid waste (MSW) in the country, the currently dominant method is landfilling. However, as many communities have been running out of landfill space and waste management costs have been rapidly increasing, MSW issues have grown in significance. Some cities have resorted to shipping their garbage to other locations, at tremendous costs. While there are differing opinions about the severity of the problem, experts agree that it has the potential for producing serious economic and environmental consequences for virtually every segment of society. Cities, counties and States in every part of the country are working to reduce waste through source reduction, recycling and other measures instead of landfilling. (EPA,1990/FDL,1989/NYS,1988)

According to New York State's update report, New Yorkers need to move rapidly from the land disposal-oriented approach of the past to a system of integrated MSW management. "Management" means treating solid waste as a resource whose value is to be recovered as much as possible and choosing methods of waste handling and disposal which are environmentally acceptable. The solid waste management system should integrate reduction, recycling, recovery and disposal. To promote integrated solid waste management, the State advances the concept of the solid waste management method hierarchy, or order of preference.(NYS,1988) This order is very similar to the hierarchy of waste management minimization options that is suggested in "The Solid Waste Dilemma : An Agenda for Action" published by the United States Environmental Protection Agency (EPA). EPA also encourages the use of waste management options other than landfilling. The order of hierarchy for both EPA and New York State is as follows :

1. Source reduction (EPA), Waste reduction (NY)
2. Recycling (EPA), Recycling and reuse (NY)
3. Incineration with energy recovery and landfilling (EPA), Waste-to-energy and Landfilling (NY) (EPA,1990/NYS,1988)

Although source reduction and recycling are EPA's preferred options, landfilling and incineration are essential components of an integrated waste management system. Of the latter two disposal options, EPA does not have a preference. Each community should consider all the options and select a system that can best handle its waste stream. According to EPA, in 1986, the principal management method for MSW was landfilling (80 percent), the rest of the MSW was handled by incineration (10 percent) and recycling (10 percent).(EPA,1990)

Economic analysis has been used in decision-making in the MSW field. For many years, landfilling was viewed as the most inexpensive method of handling MSW. Unfortunately, in many cases, problems with this inexpensive method are now costing millions to correct. These costs were not included in the analyses. While recycling has always done its share in helping to manage waste, until recently the economics of recycling was based on the value of the materials being collected, not the cost of disposing of the materials by alternative methods. In general, as the cost of alternative disposal methods escalated, recycling has become a more economic alternative.(BIO,1990)

Recycling could save the energy and raw materials used up in production, distribution and disposal of the packaged foods, drinks and other products, and as a result it would contribute towards achievement of environmental protection. Thus, recycling is an important subject for solving the problem of increasing packaging wastes.

In 1980, the public, commercial organizations and industry spent more than $32 billion nationwide on packaging in the U.S.A. (equal to four percent of the gross national product). By far, the largest user of consumer packages is the food industry, followed by the beverage industry and manufacturers of chemical products. In 1986, packaging-related waste accounted for one third of New York State's MSW stream. If recent per capita use rate increases hold true for the coming decade, the average resident in the State will purchase a half-ton of packaging materials by 1996, generating some 900 pounds per capita of packaging-related wastes. (NYS,1988)

Decreasing the problems of packaging disposal will depend on legislation, government cooperation at the intrastate or federal level, and public support. Buying habits may prove to be the determining factor in changing packaging procedures. To this end, government should educate the public regarding the importance of purchasing goods packaged in recyclable materials. New York State will be investigating the potential of coding packaging as to its compostability and recyclability.(NYS,1988)

Nearly all of the collection, separation, and processing alternatives in the U.S.A. described below have been successfully implemented in at least a few locations across the country. For many of these alternatives, however, only limited data exist from which to extrapolate costs, participation rates, technological or institutional barriers, and other factors that will determine their long-term viability. For this reason, much of the following discussion of the outlook for each alternative is qualitative, and is dependent on several documents that are edited based on the experience and opinion of participants in ongoing recycling efforts.

1. Benefits and tradeoffs related to recycling activities

Recycling projects should be part of all local government solid waste management programs. Savings realized through avoiding the increasing costs of disposal and potential revenues from the sale of recovered materials to markets will provide the financial impetus for recycling. EPA prefers this as one of the solid waste management strategies according to "The Solid Waste Dilemma : An Agenda for Action" published by the Agency's Office of Solid Waste.(EPA,1990) In addition, a program designed to provide incentives for industries to use secondary or recovered materials in manufacturing should be implemented.

Benefits from recycling programs include (EPA,1990/NYS,1988) :

* Avoiding expensive land disposal costs
* Receiving revenues from the sale of recycled materials
* Reducing the volume of waste to be landfilled
  Recycling is a method of reducing the quantity of net discards of MSW by recapturing selected items for additional productive uses.
* Saving energy by using recovered materials in manufacturing
  Plastics recycling offers the potential to generate demonstrable savings in fossil fuel consumption, both because recycled plastics can displace virgin resins produced from refined fossil fuels, and because the energy required to yield recycled plastics resins may be less than that consumed in the production of resins from virgin feedstocks.
* Improving combustion in waste-to-energy facilities by removing metals and glass from the waste stream
* Preserving raw materials for future generations

Although recycling has benefits as mentioned above, it is not without trade-offs in a great range of fields. It is important to acknowledge the existence of various trade-offs in every step of recycling systems and examine their impacts on implementation of the recycling programs case by case.

1) The more communities become involved with recycling, the more they will realize the tradeoffs in efficiencies involving overall waste (including recyclable materials) collection versus overall handling of recyclables. The

analysis of recycling alternatives suggests a trade-off between cost effectiveness and waste diversion.(BIO,1990/Polk,1991) Each individual community must evaluate its own situation independently to determine where compromises in the efficiency of delivery of individual components of the overall solid waste management system service may be merited in the interest of overall system efficiency.(Vile,1989)

2) Decisions made in household preparation affect participation rates and resale value of the recyclables, in opposite ways. For example, when towns ask households to remove labels, rinse bottles, or remove metal caps from glass bottles, there is a positive effect on quality and, therefore, on market price. At the same time, though, residents may perceive that the extra preparation is inconvenient and elect not to recycle their glass. Of course, this result would defeat the purpose of the program. It is important, then, to consider the tradeoffs that exist with these decisions.

3) In deciding the best method for handling and disposing of MSW, local governments are faced with tradeoffs. "The tradeoffs involve balancing programs and allocating limited funds among competing community needs. A community developing a solid waste management program must balance the program's cost with the cost of the community's other social and public needs - public library, sewer and water service, new sidewalks and street lights, and police and fire protection. Where a community chooses to spend tax dollars usually depends on where a community is willing to cut back financial support - therein lie the tradeoffs. Tradeoffs are made on a case-by-case basis, taking into consideration the urgency of garbage disposal needs, the amount and cost of environmental protection, the short- and long-term plans for community growth, and other pressing community needs."(NYS,1988)

4) For plastics recycling strategies, there is a political conflict between recycling and use of degradable plastics. Since the physical strength of recycled plastic products may depend on the purity of the recycled resins, further contamination with degradable materials has a negative effect on quality of the recycled plastic products. Identification and separation of the degradable plastics, however, may weaken the economic basis of recycling methods. Policy makers may have to choose whether to emphasize recycling or use of degradable plastics, and they will also need to identify which strategies will be employed for which products.

2. Overview of recycling in Japan

A striking contrast between the U.S.A. and Japan in terms of recycling activities may be that such container deposit legislation as has been enforced in several States in the U.S.A. has been exclusively applied to only glass bottles, especially those used for beer, in Japan. In Japan, the public seemed to highly participate in returning post-consumer glass bottles to retailers under a deposit system in the past when returnable glass bottles dominated the markets for beverage containers. However, as a wide variety of packaging materials, including steel/tin, aluminum, plastics and paper, has become available for beverage and food applications, the returnable glass bottles have lost their market share to a great extent, and at the same time consumers have become less conscious of reusing or recycling the packaging materials. In Japan, while glass bottles, especially returnable, have lost a great part of their market share for containers that are used for carbonated beverages during the past decade, PET bottles have rapidly gained their share (see **Figure 1**).

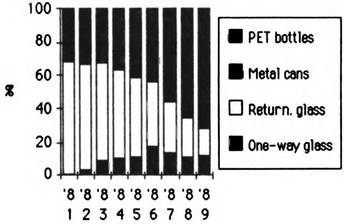

Figure 1. Trend of container materials used for carbonated beverages in Japan (1981 - 1989)
Source : JCBA, 1990

Nowadays, we can obtain various kinds of beverages and even food not only in ordinary retailers but also from a large number of vending machines located at every corner throughout the country. As a result, we can drink and eat anything we like not only at home but also outdoors at any time we want. Aluminum and plastics applied to those beverage and food packaging have advantageous characteristics, such as greater lightness than glass or steel, much higher resistance to moisture than paper, etc, although they have a negative nature as well. Since these features are beneficial to basic functions as the current food and beverage packaging, including tamper resistance, food safety, product preservation, reducing transportation cost, and easy-to-use, aluminum and plastics are likely to expand their share of the packaging market in both countries in the future.

3. Recycling of post-consumer materials

Among a wide range of categories relevant to recycling activities, the primary important distinction to be made is between recycling of industrial scrap and recycling of post-consumer materials.

In general, the industrial recycling of unprocessed raw materials, including aluminum and plastics, during manufacturing and processing operations is extensive and considerably reduces the manufacturing losses of the materials. However, because it appears that most aluminum and plastics in the MSW stream is generated from post-consumer waste rather than industrial scrap, further discussion will be limited to impacts of post-consumer aluminum and plastic recycling on the management of MSW. This study does not address the industrial recycling of these materials.

4. Focusing on aluminum cans and plastic bottles

Furthermore, this study focuses on recycling of post-consumer aluminum cans and rigid plastic containers, in particular, being used for packaging of bottled beverages.

It is evident that comprehensive recycling systems need to include collection, separation, processing, and marketing for all types of recyclable constituents in the solid waste stream. Recycling strategies made respectively for such recyclable materials as steel, tin, glass, and paper, may affect those for aluminum and plastics. However, since aluminum and plastics appear to be increasing their share of the packaging-material market in Japan, their recycling is likely to result in influencing the recycling programs for all recyclables. Thus, this study selects recycling for aluminum and plastics out of many post-consumer packaging materials in the solid waste stream.

Not all aluminum and plastics in MSW are amenable to recycling. For example, plastic trash bags by definition are intended to facilitate MSW disposal, and so are unavailable for recycling. Many or most plastics films used in food contact applications may be inappropriate for recycling because currently practicable collection alternatives require consumers to store plastics before collection, yet valid concerns regarding odors and potential health risks from food-contaminated wastes may make storage of such items impractical. The story is much the same for aluminum foil.

In addition, for the aluminum and plastic industries, it is obvious that establishment of efficient recycling systems for post-consumer cans and bottles will help keep the current increasing trend of their sales in food and beverage packaging markets on a long term basis.

Therefore, this study will exclude both plastic films and aluminum foil being used for flexible packaging and/or composite containers, and include only used beverage cans (UBC) and rigid containers among a great variety of aluminum and plastic products.

5. Identifying characteristics of recycling for aluminum and plastics

This study distinguishes recycling technologies applied to plastics from those to aluminum. As will be shown, recycled plastics represent a mixed batch for recycling due to the variety of resins in the waste stream. This contrasts with the relatively homogeneous recycled materials that can be derived in aluminum recycling. The mixed nature of most post-consumer plastics has a significant influence on the methods adopted in plastic recycling programs.

Traditional recycling of packaging materials has largely been limited to metal cans, glass bottles and corrugated papers. The recycling of post-consumer plastics, however, is relatively new to the environmental scene. For many of the alternatives for plastic recycling, only limited data exist from which to extrapolate costs, participation rates, technological or institutional barriers, and other factors that will determine their long-term viability. For this reason, much of the following discussion on plastic recycling is qualitative, and is based on the experience and opinion of participants in ongoing recycling efforts.

6. Four phases of recycling activity

1)Collection. As with all other recyclable materials, both aluminum and plastics must be segregated from other MSW constituents and collected for transfer to processors.

2)Separation. Aluminum cans must be separated from steel and tin cans. Post-consumer plastics include a variety of resins. It is not necessary to separate plastics by resin type to allow their recycling, but separation by resin allows the production of the highest-quality recycled products.

3)Processing. Once packaging materials are collected, they must be processed. A number of processes are used to manufacture recycled products. For plastics, in particular, there are three distinctive categories for processing, including primary, secondary, and tertiary processes.

4)Marketing. While the most important reason for recycling programs to pool their materials is to increase the revenues that a community can receive, in fact the stability that a cooperative marketing offers outweighs the chances for increased revenues in terms of importance. The biggest reason for establishing a cooperative marketing program is certainly the stability it can bring to the community's recycling.(NYS,1988/BIO,1990)

Since demand for aluminum UBC is apparently stable, marketing efforts for collected aluminum are less than for plastics. Homogeneous recycled resins may be processed into products that compete in markets with virgin plastics. With currently available technologies, most mixed recycled plastics are processed into generally lower value products that compete in markets with materials such as lumber and concrete.(EPA,1990)

These four phases of recycling activity are closely related. For example, the extent of separation among plastic resins achieved during collection largely determines the types of processing available and the products that can be manufactured from the recycled resins. Marketing considerations, in turn, determine the marketability and value of these products, and drive the economic calculations by which the viability of the entire recycling chain is evaluated.

7. Alternative methods of collection

For collection strategies, five major alternatives appear to exist. They can be entitled as (1) voluntary container buy-back systems, (2) drop-off recycling centers, (3) curbside collection programs, (4) container deposit legislation, or bottle bill, and (5) reverse-vending machines. Each of these strategies will be analyzed in terms of their merits and demerits for implementation of recycling for both post-consumer aluminum and plastic containers in Part One.

8. Source separation options

Besides the alternative methods of collection as mentioned above, there are three other distinctions including home separation, curb separation and commingled collection according to whether separation is made before collecting recyclables at the curbside or after collecting at either a recycling center or drop-off site. If home separation restricts participation and curb separation slows down the collection process, then it would appear that a system that allows for commingled collection would be advantageous.

Source-separation programs tend to be the most successful when consumers are asked to do relatively little separation. For example, a multi-material recycling program collecting glass, metal, and paper will have a higher level of participation if consumers are asked to put all recyclables in one container, than it will if they are required to further separate glass from metal from paper.(Selke,1988)

Unfortunately, commingled collection may require the development of fairly expensive processing facilities because it will always require the separation of recyclables from the commingled waste materials after collection.(BIO,1990) In the two cases of home and curb separation, the degree of separation would be another important factor from an economic viewpoint.(BIO,1990/EPA,1990)

9. Cooperation of governments, industries and residents

A key factor in a successful community recycling program is the level of public involvement. National and local governments, industries, and individual citizens must cooperate with each other for increasing public awareness and participation in recycling programs. In order to maximize the public participation, especially in the phase of recyclables collection, it is usually necessary to initiate an education program. This may take many forms, but the direct contact between the collector of recyclable materials and the generator of those materials is usually a key component of any effective program.

PART ONE
ALTERNATIVE COLLECTION METHODS

Integrated recycling systems are composed of four phases, including collection, separation, processing and marketing. For collection strategies, five major alternatives appear to exist which can be entitled as (1) voluntary container buy-back systems, (2) drop-off recycling centers, (3) curbside collection programs, including separation options, (4) container deposit legislation, or bottle bill, and (5) reverse-vending machines. Each of these alternatives will be discussed in terms of their advantages and disadvantages for implementation of recycling for both post-consumer aluminum cans and plastic containers in this part.

In addition to planning these collection methods, for a municipality, actual enforcement of mandatory ordinances determining citizens' responsibilities for the collection of recyclable materials will be of importance for increasing the effects of recycling programs. With a mandatory ordinance in place, the municipality has an opportunity to do more than suggest people cooperate. It can insist that they cooperate. Just the act of passing the ordinance helps the program by publicizing and giving it legitimacy. While passing an ordinance helps establish its legitimacy at the outset, enforcement is important because it shows citizens the municipality is serious about recycling and means to sustain the program. This issue also is described below.

Chapter 1. Voluntary Container Buy-Back Programs

In a voluntary buy-back system, consumers bring designated recyclable items to a central facility where they receive a cash payment on a per item basis. These systems differ from container deposit systems in that the designated items are purchased without a deposit. Buy-back programs may be implemented by private organizations (e.g., beverage industry groups) or by government authorities.(EPA,1990) In efforts to ensure a constant supply of secondary raw materials, it can be expected that the manufacturing industry will continue to diversify and possibly integrate vertically. Many manufacturers will look to national service companies to form partnerships, similar to the Browning-Ferris Industries-Wellman, Inc. partnership for collecting and consuming scrap plastics. But they will also continue relations with long-term, reliable suppliers, even charitable organizations. Some producers will get into the business of collecting the raw materials themselves, which may involve setting up buy-back centers or commercial recycling companies. In some areas, these collection subsidiaries will even get into the business of waste hauling or disposal. (BIO,1990)

In States which do not have bottle deposits, buy-back recycling centers are often set up either in or near stores. Store owners have found that the recycling centers can increase consumer goodwill and bring in more business. In addition, most consumers bringing cans in to be recycled will spend the receipts in the store. Some western States have achieved recycling rates for aluminum cans up to 60 percent by this buy-back form of voluntary recycling.(Folz & Hazlett,1990)

On the negative side, these programs are not likely to divert significant quantities of recyclable materials in the MSW stream to recycling programs, although they can be successful at the local level. Like drop-off centers, these systems face the disadvantage that they require consumers to store recyclables and bring them to a central recycling location. Buy-back systems also may be impeded by the need to balance payments made to consumers with the economic value of the recycled products. Payments to consumers sufficient to induce high participation rates are likely to impose serious financial burdens on the sponsor of the program. The economics of these programs remain poor, however, because the sponsor does not participate in savings attributable to reduced landfill requirements.

(EPA, 1990)

For the above-mentioned reasons, voluntary buy-back programs are likely to remain a nationally minor contributor to the success for both aluminum and plastic recycling in Japan as well as the U.S.A.

Chapter 2. Dropoff Recycling Centers

Section 1. Advantages and disadvantages

(i)Advantages

First, the development of a dropoff program can provide a community that is just becoming involved in recycling with a relatively inexpensive learning experience.(BIO,1990) Their primary advantage over curbside programs is their relatively low cost to the community, because they require minimal equipment, personnel and maintenance. In addition, collected materials are generally clean and of high quality.(EPA,1990)

Second, in those areas where waste disposal is still cheap, a dropoff program may be the only option that is economically feasible.(BIO,1990) They may also be the only practicable collection alternative in communities that do not provide for MSW collection but that require consumers to bring their wastes to a central collection facility.(EPA,1990)

Third, rural areas are also good candidates for dropoff programs because low population densities make curbside collection impractical. At the other end of the spectrum, high-density population areas, such as apartment complexes and inner cities are prime locations for dropoff programs. (BIO,1990) Dropoff recycling centers are likely to continue to be implemented among States and municipalities that are hesitant to face the costs and institutional requirements of curbside recycling or in which curbside pickup is infeasible.(EPA,1990)

(ii)Disadvantages

Dropoff center programs require consumers to store recyclables at home and transport them to a central location. Residents may be unwilling to both sort and deliver recyclable materials, resulting in low participation rates.(NYS,1988) Participation rates of this option tend to be initially high, and then diminish significantly, unless the sponsoring agency implements continual efforts for effective public education. Because of the historically low participation rates, drop-off centers may not promise to divert a large proportion of recyclable materials from disposal.(EPA,1990)

Section 2. Compatibility with curbside programs

Study after study into recycling options has downplayed the importance of dropoff programs and moved more and more communities into curbside collection. Some voluntary dropoff centers are forced to shut down, because other collection alternatives such as deposit laws and curbside pickup programs have been adopted in communities and, as a result, a significant proportion of valuable aluminum cans are diverted into those collection options. However, dropoff programs have also proven to be very effective as adjuncts to curbside programs. As strange as it may sound, providing dropoff sites when a curbside program is available adds to a program's overall convenience.(BIO,1990/EPA,1990)

"While many people expect tonnages at dropoff sites to fall drastically after a curbside program is initiated, in many instances the opposite occurs. When a pilot curbside started in Durham, North Carolina, for instance, the material collected at dropoffs actually went up. The same thing occurred in the Town of Bloomsburg, Pennsylvania, which has a monthly curbside program along with a series of four dropoff sites. In a pilot program in Everett, Washington, a dropoff program actually performed as well as a curbside program. In Champaign County, Illinois, tonnages at dropoff sites initially fell by about 35 percent but within a year began to rebound, even though a number of dropoff sites were eliminated. If a citizen misses a collection day or is planning to be out of town, the dropoff site will be there. Dropoff facilities also can be used to expand the types of materials a program accepts by providing a place where hard-to-collect materials such as plastics, corrugated paperboard, batteries and motor oil can be received." (BIO,1990)

Section 3. Location of dropoff sites

The primary variables defining implementation strategies for drop-off centers include :

1. Number and location of recycling centers in the community
2. Degree of recyclables separation required
3. Hours of operation

Beyond public education, the most important element of a dropoff program is locating sites where they are convenient to citizens. Many of the dropoff programs that have been put in place simply were not designed to encourage maximum participation or remove substantial quantities of materials from the solid waste stream. While dropoff programs are the most common form of community-based recycling, the vast majority of programs are run by nonprofit groups as fundraisers. As such, most are operated at the convenience of the organizer, not the public.(BIO,1990/EPA,1990)

In large communities, more than one collection facility would probably be needed to achieve high recycling rates, since participation rates are likely to decline as distances increase from an individual's residence to the dropoff center. "Residents will patronize a center within three to five miles of their home, combining the recycling trip with other errands. The best location for sites seems to be at a shopping center or grocery store. Other likely candidates are schools, churches and fire stations. Many of the most publicized and successful dropoff programs (such as Wellesley, Massachusetts and Wilton, New Hampshire) have been located in conjunction with the communities' garbage dropoff facilities, providing one stop trash services. In areas where citizens must haul their own trash, this approach seems ideal. However, in communities where trash is picked up from the home, dropoff sites are best located at facilities which residents frequent on a regular basis, so that they do not have to go out of their way to participate."(BIO,1990)

"When a dropoff system is designed, it is necessary to look at population distribution, traffic patterns and the location of shopping centers. One of the principal overriding factors is that a site owner wants to have the dropoff on his property. One rule in planning a network of dropoff sites is to have a site for every 5,000 to 10,000 residents. But according to Michigan's Recycle Unlimited, it is more important to look at where the residents are traveling to, rather than blindly providing sites for every so many people, and adjust the storage capacity at the site to meet the demand."(BIO,1990)

In addition to the location of the sites, physical layout is important to the program's success. A site must be placed in an area where the people using it feel secure. In many instances, this is done by placing the site in a well traveled location visible to passersby. Such a location also helps to keep illegal dumping to a minimum. To keep litter from being a problem, it is also good to provide trash receptacles.(BIO,1990)

"According to William Healey of Recomp, Inc. in Bloomington, Minnesota, transfer stations provide a point at which various components of the waste stream can be rerouted, and not just transferred for transport to the landfill. These facilities should be utilized to stop the flow of materials and redirect them to other places. Transfer stations are an ideal place to integrate recycling and composting because it builds in the least amount of travel for materials."(BIO,1990) In the past, transfer stations were designed for one purpose: transferring refuse from collection vehicles to transfer trailers. However, over the last several years, various forces, such as diminishing landfill capacity and skyrocketing tipping fees, have combined to alter the considerations on transfer station design and operation.(BIO,1990)

Section 4. Better definitions and standards

As the number of sites, so-called recycling centers, is increasing, more specific definitions and standards for the recycling centers are needed to protect the public against abuses. For instance, New Jersey, where recycling facility operators are not required to obtain solid-waste-facility permits, defines a recycling facility as one that produces minimal residue. However, it has no definition of what minimal residue is. "If a facility recycled greater than 50 percent of its incoming waste, for example, is it a recycling facility or a transfer station? Classification as a recycling facility could save the operator significant amounts of time and money. To help clear up the issue, a bill has been introduced in the State legislature that would define minimal residue as 10 percent of the incoming waste." (Vile,1989)

"Whether or not a recycling facility is a transfer station is equally important in areas where out-of-town waste is prohibited from disposal facilities. In Connecticut, trash generated in a particular locality must go to the same locality's disposal facility. Since recycling centers are in a sense considered manufacturing facilities, the residue they generate is permitted at local disposal facilities. Without a clear definition of a recycling center, this has opened the way for trash transfer stations to claim to be recycling centers in order to gain access to local disposal facilities. Otherwise, after the transfer station had recycled part of the load, the operator would be required to return the residue to the originating town's disposal facility. This has led the Department of Environmental Protection to develop the initial criteria that a recycling center must recycle 80 percent of the material it receives. If more than 20 percent residue is generated then the facility is a transfer station. The Department plans to further refine these percentages for specific types of waste when better data is available."(Vile,1989)

The fact that operating requirements for recycling centers are much less stringent than for transfer stations in many states has also created problems. "In California, franchise holders for municipal refuse collection must meet strict operating requirements. Unregulated recycling companies, however, are able to undercut the franchise holder in bids for commercial refuse hauling because of the lower standards they must meet as recycling centers, even though they are providing a similar service."(BIO,1990)

These examples point out the need for well-thought-out guidelines governing recycling centers and transfer stations. The current advantages recycling centers now receive have led companies to abuse the system that was meant to give recycling a boost. To rectify this, definitions need to be developed for transfer stations, transfer-recycling stations and recycling centers. A transfer station simply transfers waste, with little if any reduction in the quantity of waste sent for disposal. For example, here is one recommendation regarding the guidelines. "A transfer-recycling station should remove at least 25 percent of the waste received for recycling. A recycling center should not be allowed to generate a residue greater than 5 percent of the material received."(Vile,1989)

Section 5. Examples in small towns

A transfer station to be built in Keokuk, Iowa, will be used to transfer recyclables and non-recyclables. A curbside collection program will get underway in the town, and will be operated by the Lee County solid waste department. The plan calls for hauling all the collected recyclables to a recycling center in Fort Madison, which is 22 miles away. The department will be putting large containers at the new transfer station in Keokuk for the curbside collection vehicles to use. The collections will be done on a biweekly basis. The county anticipates a 40 percent reduction in the volume of MSW to be landfilled. About 15 to 20 percent of the incoming waste stream is yard waste.(BIO,1990)

Section 6. Systems for dropoff collection

In general, drop-off system consists of a series of subdivided, unattended (or occasionally attended) containers located throughout a community. Recyclable materials are collected with a truck and transported to a processing facility.

In basic terms, three types of commercially available collection systems for dropoff sites seem to be specified. They are rolloffs, small bins and specialized containers. Each type of container utilizes a different type of collection system. The specialized containers can be emptied on site, while rolloffs must be transported to a processing facility or market prior to unloading. The smaller bins can either be emptied on site or removed to be emptied, depending on the system that is put in place.(BIO,1990)

1) Specialized containers

Although this type of container used to be a dome-shaped fiberglass container, recently it has changed to a rectangular metal container. (BIO,1990)

2) Small bin and rolloff systems

Small bin systems utilize containers in the two to three cubic yard range. In most cases, the bins have a single compartment and are used to collect one type of material. In general, the rolloffs are single compartments that receive a single material. However, in some instances, the rolloffs are compartmentalized so that more than one material is collected per container.(BIO,1990)

3) Apartment and condominium containers

Profile Recycling Container for apartment or commercial multi-material collection, which is offered by Fibrex, is available with one, two or three compartments, creating separate volumes of one and six-tenths to eight cubic yards. Internal walls available in several different shapes allow compartment size to vary depending on volumes of materials collected, without changing the external size and appearance of the container. Internal compartment size can be changed at any time.(BIO,1990)

Chapter 3. Curbside Collection Programs

Section 1. Advantages and disadvantages

(1)Advantages

First, curbside collection allows households to set their recycling containers out in a visible location, thereby validating their support for recycling. As will be mentioned in Chapter 6, St. Louis Park, Minnesota, provided residents in the curbside program with recycling containers for convenience, reminders and as a peer pressure tool. The peer pressure to participate will be encouraging households to recycle.(BIO,1990)

Second, curbside pickup gives residents a more convenient opportunity to participate in recycling programs. Although more costly than dropoff collection centers, curbside collection programs show a higher rate of participation than do collection center programs. In addition, if source separation is required by local ordinance, curbside collection provides the best means of enforcing participation.(NYS,1988)

Third, as a result of the above mentioned benefits, curbside pickup offers to divert the most significant quantities of MSW from disposal. Of the available collection alternatives, this strategy tends to divert the largest proportion of MSW from disposal, including glass, metal, newspapers and plastics.(EPA,1990) According to the Glass Packaging Institute, if adopted nationwide, curbside programs could reduce the solid waste stream by at least 15 to 25 percent.(FDL,1989)

Fourth, curbside collection is economically advantageous. Collection, separation and processing require expenditure of funds. Most curbside programs are funded by grants from State and regional governments.(BIO,1990) In New Jersey, communities are reimbursed for their curbside efforts based on recovery volume of recyclable materials. In Minnesota, the beverage industry works with a collection organization, Super Cycle, which services 350,000 households in the Minneapolis/St. Paul area. In general, the most significant factor offsetting the costs of recycling programs is the avoided cost of waste management. Any program whose costs for collection and processing are less than sales revenues plus avoided disposal costs is generally considered profitable.(BIO,1990) Because of the increase in tipping fees, in the U.S.A., disposal fees plus revenues from sale of recyclables usually exceed the cost of collection and processing.

(BIO,1990/EPA,1990)

Nearly 600 curbside collection programs have been established in the U.S.A. and now they are still in effect.(FDL,1989) Overall, more than 2 million households participated in curbside collection programs in 1988. (Schell,1989) Along with the onset of mandatory recycling laws in States such as New Jersey, Pennsylvania, Rhode Island and Connecticut, the popularity of curbside programs is likely to grow in the country. Curbside program participation varies from place to place, but generally ranges between 10 and 90 percent of households monthly.(FDL,1989)

For plastics, a newfound source of post-consumer plastics is the curbside collection program. While not a new development, curbside collection programs have recently become a major supply factor. The supply problems for plastic recycling are expected to be taken care of eventually by greatly expanded mandatory recycling programs which will provide curbside pickup for source-separated plastics.(Selke,1988/Schell,1989) Further discussion on the curbside collection that includes plastics will follow in Chapter 11.

(ii)Disadvantages

On the other hand, curbside programs face a number of institutional and economic barriers.

First, this option is probably not feasible in communities that do not currently provide MSW collection (or curbside pickup by private haulers) and/or have low population densities, or in rural areas with no centralized MSW collection services.(EPA,1990/Henry,1989)

Second, this option may also face significant hurdles to implementation in urban environments with large numbers of multi-family residences. Most of the curbside programs currently operating are in suburban settings with few multi-family dwellings. If curbside collection is to capture a significant proportion of urban MSW, unique difficulties are imposed by the presence of a large number of multi-family dwellings.(EPA,1990)

For both the U.S.A. and Japan, in general, the difficulties faced by urban collection programs, which may have a significant impact on the net cost of recyclable collection programs, are as follows :

* Lack of storage space in many apartments/condominiums - Many urban residences are small, and very few have garages or other unused space for

recyclable storage.(EPA,1990)

* Widespread use of dumpsters - Many multi-family residences use one or more large containers for MSW collection. Implementation of a recycling program implies using additional containers for recyclables collection, for which little space may be available in urban settings.(EPA,1990)
* Difficulty of access for collection vehicles - Narrow streets and alleyways may impede vehicle access to collected recyclables, and may make collection a very slow process, adding significantly to program costs.(EPA,1990)

Third, while the nine bottle-bill States account for nearly all of the plastic that is being recycled today, many curbside programs exclude plastics because of their high volume/weight ratio.(EPA,1990/FDL,1989) The issues related to the lightness of plastics will be discussed further in Chapter 11.

"Curbside programs currently serve less than 10 percent of the population, with most of the recovered materials coming from the commercial sector. In fact, less than 4 percent of Seattle's highly touted 38 percent recycling rate comes from its residential curbside program. Likewise, only 3 percent of Newark's lauded 41 percent recycling rate comes from residential curbside recycling."(Henry,1989)

Section 2. Background Information

Probably the most fundamental decision that needs to be made concerns who will actually collect the recyclables. "Will the town contract with a private company or organize its own municipal collection crew? This decision process usually starts with an assessment of current practices for collecting regular refuse. If under contract, can the same company also handle collection of recyclables? Are there other companies that would be willing to bid their services? If the town is currently doing its own refuse collection, what is the feasibility of adding recyclables - from the standpoint of labor resources, administrative resources, and available equipment?"(BIO,1990)

The background information that is necessary to gather is the same, regardless of who collects the recyclables. It includes determining:

* Volume of regular refuse
* Anticipated volume of recyclables

* Number of households to be serviced
* Characteristics of community such as geography and single-family versus multi-family residences
* Other recycling activities such as incinerators, local legislation or bans on materials, etc., being planned or currently in operation
* Status of available landfill space

Section 3. Participation rate as a key factor

There are literally hundreds of combinations of specific program parameters that can be considered when planning for curbside collection. Planners need to consider which materials to collect, how to collect them, how to determine all associated costs and expected revenues, and how to maximize participation rates. And participation rate appears to be the single variable most critical to determining the overall net economic cost or benefit of curbside collection. While the absolute value of operating costs (and potentially of capital costs as well) rises with increasing participation, the marginal capital and operating costs per ton collected fall. The marginal cost of processing also falls as participation (and tonnage collected) increase. On the revenue side, dollar-per-ton sales prices for recyclables are unaffected by increasing participation, and may actually increase if the additional tonnage allows a municipality to negotiate higher prices for its recycled materials. Effective promotion and publicity for recycling programs can be critical to achieving and maintaining high participation rates in curbside programs. Because many very effective promotional tactics can be implemented at low cost (e.g., bulk mailings, "doorknob" literature, articles in local papers), the net benefits of promotional campaigns appear almost universally to outweigh their costs.(BIO,1990/EPA,1990)

The Center for Plastics Recycling Research (CPRR) completed an extensive computer modeling study of the costs and benefits of curbside collection and multi-material recycling in 1988. Validated against the experience of five New Jersey recycling programs, this study confirms that curbside programs offer a net economic benefit under most plausible operating scenarios. The CPRR study also confirms that participation rate is the single most important variable affecting collection program economics, and demonstrates the importance of avoided tipping fees in determining the net economic impact of curbside recycling. Common to many of these program design parameters is their impact on participation rates in recycling programs.(EPA,1990)

Section 4. Elements to increase the participation rate

(i)Frequency of collection (weekly, bi-weekly, monthly, etc.)

In general, high frequency of collection can remove the need for long-term storage of recyclables at home. There are several points to consider with regard to frequency. First, to what degree would pick-up frequency affect the total tonnage of recyclables collected? Weekly collection seems to be best in terms of volume generation. Second, a town that operates less frequent collection may choose to provide larger storage containers to households than a town that collects more frequently.(BIO,1990/EPA,1990)

(ii) Degree of recyclable separation required/single container (commingled) versus separate containers

This choice includes all recyclables placed in one container, or paper separated from all other recyclables, or paper, metals, glass, and plastics separated into individual containers. This single decision can affect several phases of a program. The vehicle design for collecting source-separated materials is different from that used for collecting commingled recyclables, e.g., multiple compartments versus one compartment. Also, commingled recyclables will need to be further processed i.e., separated (by collection crew, recycling center, etc.) before they can be sold. (BIO,1990/EPA,1990) Minimal requirement for separation of recyclables, for instance three or four categories, appears to be a practicable maximum, from the standpoint both of consumers and of municipal collection teams.(EPA,1990)

(iii)Municipality provides its residents with containers for recyclable storage and curbside set-out.

Providing each household with a suitable container for recyclables has a significant positive effect on the participation rate.(BIO,1990/EPA,1990) It serves as a visual reminder to separate recyclables from non-recyclables and, come pick-up day, encourages participation by way of neighborhood peer pressure. Nobody would want to be the only one on the block who has not set out their recyclables.(BIO,1990)

For example, in St. Louis Park, Minnesota, from the beginning of its curbside program, the city provided residents in the program with recycling containers for convenience, reminders, and as a peer pressure tool. Because the program collects separated materials - paper, glass and metal (and recently plastic bottles) - a three bin stackable system was selected. Today, with more than 80 percent of its citizens participating, the recycling program averages between 200 and 250 tons of material monthly, more than 2,500 tons annually.(BIO,1990)

(iv)Same or different day as MSW collection

Collection of recyclables on the same day as collection of other MSW should be most simple for residents and as a result the participation rate might increase.(BIO,1990/EPA,1990)

"Islip, New York, began a source separation program called WRAP in 1980. The key to the town's success has been a simple, uniform collection system combined with an innovative and comprehensive education program. In the Islip program, all recyclables are collected on Wednesdays. Newsprint, corrugated cardboard, mixed paper, aluminum and tin cans, and all glass containers are commingled in a single 20 gallon container that the town has provided each residence. With the exception of the 10 districts where garbage is collected by the town and municipal crews do the work, the pickup of recyclables is performed by the same private collectors in the same trucks that are contracted to collect garbage. The fundamental concept in the residential program is simplicity - one collection day, one container."(BIO,1990) Also, in many other cities of New York State, recyclable collection is made by the same municipal crews or private hauler responsible for picking up the regular trash.(NYS,1988)

Section 5. Other elements for success

(i)Other basic factors in program specifications

The basic factors other than the above mentioned are as follows :

* Implementation of a curbside collection program involves choices regarding whether participation will be mandatory or voluntary. (EPA,1990)
* Assess market for recyclables - This process is important because of the

need to (1) verify that a market exists for each material that is being collected and (2) ascertain current market price for each recyclable so that revenue data can be included to offset the total cost of the recycling program.(BIO,1990)

* Material(s) to be collected - The degree of control a municipality has over this variable will be different from town to town. Some governmental bodies, when they mandate recycling, will specify which materials are to be collected. Others will, instead, allow each municipality to determine its own mix of materials, but will set a mandatory goal for the percentage of total solid waste that must be recycled. For those who have responsibility for determining material mix, it is important to consider the particular costs, revenues, and labor productivities associated with each recyclable material, because they vary by material.(BIO,1990)
* Hours of collection and daily routing - Hours and routing should be planned to avoid traffic congestion as much as possible. This will allow for greater crew productivity in a given amount of time.(BIO,1990)
* Day(s) of collection - Participation rates may vary with the day(s) that recyclables are collected. Collection crew productivity has also been found to vary by day of the week.(BIO,1990/EPA,1990)
* Ownership of recyclables - Some towns choose to retain ownership of the materials collected and to pay a private hauler for the household collection process only. While this may result in a higher collection fee, revenues will be realized from the eventual sale of the recycles. Additional costs may be incurred, however, that relate to the processing and marketing of the materials. Curbside pilferage of materials, especially aluminum, can become a concern to municipalities that rely on revenues generated from the sale of recyclables collected.(BIO,1990)

(ii)Example of financial incentives

St. Louis Park, Minnesota, is a fully developed urban community in the first ring of suburbs around Minneapolis. Its 43,000 residents are housed in 12,000 single family homes, 400 duplexes, 2,000 townhouses and condominiums and 5,000 apartment units. Garbage collection for all single family through four-plex homes is provided by a single hauler under contract to the city.(BIO,1990)

In 1982, the city began a twice-monthly curbside program that accepted glass, cans and newspaper. Today, with more than 80 percent of its citizens participating, the recycling program averages between 200 and 250 tons of material monthly, more than 2,500 tons annually. This has been accomplished not by mandating that citizens participate but by educating its citizens, making it convenient to participate and giving them a financial incentive for doing so.(BIO,1990)

"In 1986, the city surveyed citizens about improvements in the program. One finding - 94 percent preferred economic incentives as a means of promoting recycling. Conversely, 51 percent were opposed to mandatory recycling requirements. Using this feedback, the city established a garbage service charge that would give participants a financial incentive. What the city hit on was a tiered garbage rate structure. As of February 1, 1988, the base rate for garbage collection in the city was set at $11.00 per household per month. A recycling credit is issued to residents who recycle at least three times within a quarter. No credit is given for less than three times. This assumes once per month participation, although the resident may participate any three times out of the six possible opportunities. Because there are other recycling options open to the citizens, including buyback centers and nonprofit organization recycling efforts, the city also provides a credit to citizens who use those services, if they return at least one recycling voucher from the organization to the city."(BIO,1990)

(iii)Innovative monitoring systems

St. Louis Park, Minnesota, indicates also the features of innovative monitoring systems which utilize a bar code method. In St. Louis Park, bar codes are used to track a household's participation in the curbside program. "When the program started in February, 1988, the city had to employ people to ride on recycling vehicles to record each recycler's participation. That list was then entered manually into the town's computer so that a recycler's bill could be discounted. The system was slow and costly. In November, 1988, every household serviced by the recycling program was sent a set of bar code stickers to place on their recycling containers. Each set of bar codes containers the household's utility billing accounting number. When a citizen sets out the recycling containers, the recycling collector uses a hand-held scanner to record the account number of the participant. At the end of each collection, the data from the scanners is transferred electronically to the utility billing office's computer. Each time a household participates, the computer updates the information. If that household participates three times a quarter, its bill is automatically credited. In addition to providing accurate information for billing purposes, the bar code method also provides an accurate means of constantly monitoring collection day and monthly participation. The entire monitoring program, including creating the bar codes, purchasing the hand-held scanners and computers, documentation and training, cost the city approximately $25,000, less than the labor price tag for the old system." (BIO,1990)

Section 6. Program design elements affecting costs and benefits

In the U.S.A., a number of researches into the economics of curbside collection have provided sources to assist municipal officials in estimating recycling program costs and benefits. Some of these studies have provided information on specific cost components (e.g., equipment costs), or have provided ranges of costs for major recycling program elements (e.g., labor, operation and maintenance). However, none has provided comprehensive information on the costs and revenues of specific municipal programs. (BIO,1990/Henry,1989)

Overall program costs and revenues are determined by the interaction of a large number of cost elements. Some of these are influenced by the design of the recycling program, while others are more or less independent of the program setup. Because these program design elements often interact, and because changes in more than one element are often implemented simultaneously, it is difficult to isolate the impact of specific design elements on program costs and revenues. With this caveat, however, a number of general observations can be made and they are shown below.

(1)Collection strategy and crew size

Some studies have suggested that it is most cost-effective to collect MSW and recyclables simultaneously, using trailers on MSW collection vehicles.(EPA,1990) The haulers include either the municipality, private contractor or a volunteer group.(NYS,1988) In practice, however, most communities have apparently chosen to operate independent recyclables collection crews. Few data are available to suggest which option, in practice, imposes the smaller cost for recyclables collection. If separate collection is implemented, both theoretical and practical evidence suggests that a one-man crew is the most cost effective.(EPA,1990)

(ii)Collection frequency

Although increasing collection frequency (e.g., from bi-weekly to weekly collection) increases both capital and operating costs, it also tends to result in high participation rates and increased yields of recyclables. In a Plymouth, Minnesota, recycling program, tonnage collected rose from 40 tons/month to 240 tons/month when the town moved from monthly to weekly collection. In general, increasing collection frequency appears to generate a net economic benefit to the recycling program.(EPA,1990)

(iii)Providing containers for recyclables

While this option generates a capital cost, providing containers to residents is very important to generating high participation rates, and the incremental benefits far outweigh the costs of the containers.(EPA,1990)

(iv)Recyclable material sorting

Sorting of recyclables may be carried out by either residents or collection crew. If recyclables are not sorted, they will require additional processing before their sale. Requiring some sorting to be completed by residents reduces program costs for additional processing, and increases per-ton revenue from recyclable sales. On the other hand, this sorting option may increase collection costs, because more sophisticated collection vehicles are required, and may tend to reduce participation if sorting and storing a number of classes of recyclables becomes a burden on participants. In general, requiring residents to complete at least partial sorting (into two to (at most) four categories of recyclables) appears to be most cost-effective. "In some cases, however, noneconomic goals may influence the selection of a sorting option; for example, Somerset County, New Jersey requires little sorting by participants, and employs handicapped citizens to collect and then sort mixed recyclables."(EPA,1990)

(v)Promotion and publicity for recycling programs

Because many very effective promotional tactics can be implemented at low cost (e.g., bulk mailings, "doorknob" literature, articles in local papers), the net benefits of promotional campaigns and publicity appear almost universally to outweigh their costs.(EPA,1990)

(vi)Additional elements beyond program operator's control

The program parameters described above, and their associated cost and revenue impacts, are subject to control by recycling program operators. However, a number of additional cost and revenue elements are beyond such control, and have a large impact on the economics of curbside collection. The most important of these are :

* Tipping fees - Avoided tipping fees represent a direct economic benefit of recycling. They vary from virtually nothing to as much as $200 per ton.(EPA,1990) In St. Louis Park, Minnesota, the landfill fees (tipping fees) are currently in the $20/ton range. The amount of material removed from the waste stream translates directly into a reduced cost on the disposal side of the fee.(BIO,1990)
* Labor costs - Labor costs are generally the largest single operating expense in curbside programs, contributing as much as 85 percent to total annual program costs.(BIO,1990)
* Prices obtained for recycled materials - These prices are subject to wide variation, both over time and across geographic regions. For plastics, prices vary by resin type, resin mix, color, and degree of processing. For example, August 1988 prices for recycled polyethylenes were 15 to 29 cents per pound ; a year before, cleaned and processed polyethylene resins sold for only 6 cents per pound.(EPA,1990)

Section 7. Range of the costs and revenues

It is obvious that cost structures, per-ton costs and revenues, and net economic costs and benefits of curbside collection programs vary widely. **Table 1** provides information on the range of costs and revenues generated by curbside recycling programs, and the net economic impacts of these programs in seven municipalities across the U.S.A.(EPA,1990)

Table 1 - Cost information and program characteristics from seven community recycling programs

Program Characteristics	Ann Arbor MI	Montclair NJ	Austin TX	San Jose CA	East Lyme CT	Haddonfield NJ	Charlotte NC
Type of program	voluntary	mandatory	voluntary	voluntary	mandatory	mandatory	voluntary
Pick-up frequency	monthly	bi-weekly	weekly	weekly	weekly	weekly	weekly
Year prgrm started	1978	1971	1982	1985	1974	1983	1987
Materials recycled	a,b,c,d,e, g	a,b,c,d	a,b,c,d	a,b,c,d(a)	a,b,c,d,e	a,b,c,d,g	a,b,c,f,g
Required separation categories	4	2	3	3	4	3	1
Recycle and rubbish collect. crew	separate	separate	separate	separate	separate	separate	separate
Recycle and rubbish collect. day	same	separate	same	same	same	same	same
Participation rate	33%	>85%	25%	>41%	>80%	95%	>74%
No. of households	20,000	14,500	90,000	20,000	5,000	3,000	9,100
Tons collected at curbside	2,500	4,980	7,200	6,500	2,100	1,703	1,329
Collector (public or private)	private	public	public	private	public	public	public
Processing method	complete	partial	none	none	none	none	partial
Program costs							
Total capital expenditure	842,000	241,000	362,000	0	27,000	19,000	591,108
Processing facility	303,120	28,920	NA	NA	NA	NA	NA
Processing equipmt	143,140	19,280	NA	NA	NA	NA	NA
Collection equipmt	395,740	175,930	362,000	NA	27,000	19,000	591,108
Annualized capital costs (over 10 years at 10%)	138,677	39,693	59,621	0	4,447	3,129	NA

Table 1 (cont'd)

Total annual operating costs	146,323	442,500	924,000	222,124	120,325	67,500	203,100
Labor	—	261,000	615,000	—	85,335	60,000	147,100
Vehicle maintenance	—	14,500	234,000	—	6,150	7,000	18,000
Administration and overhead	—	167,000	75,000	27,418	28,840	500	38,000
Total annual costs	285,000	482,193	983,621	254,820	124,772	70,629	203,100
per household	14	33	11	13	25	24	22
per ton collected	170	97	137	39	59	41	153
Total revenue	417,500	691,960	363,400	278,524	168,000	100,900	113,449
Tipping fee savings	—	507,960	72,000	52,000	168,000	69,000	46,290
Recycled material sales	117,500	184,000	246,400	86,924	minimal	20,250	67,159
Contract fees	300,000	—	—	139,600	--	—	—
State grants/ collection fees	--	—	45,000	—	—	11,650	—
Program cost summary							
Total revenue/cost	1.46	1.44	0.37	1.09	1.35	1.43	0.56
Average sale price (per ton)	47	37	34	13	--	12	51
Total profits (costs)	132,500	209,767	-620,221	23,704	43,228	30,271	-89,651
Net profits (costs) per ton	53	42	-86	4	21	18	-67

Note: a: newspaper, b: aluminum, c: glass, d: metal, e: cardboard, f: plastic, g: misc.

(a) : Figures do not reflect recently started plastics collection programs.

Source : EPA, 1990

Some of the major findings are as follows :

1) Four of seven reporting programs calculate that the net revenues of curbside collection exceed program costs, while two other programs reported revenues nearly equal to program costs. The revenues reported from recyclable sales vary widely, from $12 per ton to a reported $47 per ton - the highest per-ton revenue was generated by the one program that processes recyclables completely prior to their sale (Ann Arbor, Michigan).

2) Total annual costs per ton collected also varied widely, from approximately $40 per ton to $170 per ton; the highest per-ton costs were again generated by the one program that processes recyclables.

3) Operating costs contributed approximately 70 percent to 100 percent of the total costs associated with the recycling programs. Real costs for the Austin program may actually be even higher, because the facilities and equipment were donated by the city at no explicit cost to the recycling program.(EPA,1990)

4) Avoided tipping fees are the primary contributor to program revenues in a number of these programs - 65 percent of revenues in San Jose, California, 68 percent of revenues in Haddonfield, New Jersey, 72 percent of revenues in Ann Arbor, Michigan, 79 percent of revenues in Montclair, New Jersey, and 100 percent of revenues in East Lyme, Connecticut. "For programs that hire a contractor to implement recycling, it has been assumed that contract payments are approximately equal to the avoided cost of disposal of the recycled materials."(EPA,1990)

"One important gap in both actual and hypothetical cost estimates concerns recycling programs in urban areas containing a large proportion of multi-family dwellings. Most of the curbside programs implemented in the U.S.A. to date have been in suburban or rural settings with very few multi-family units, and most estimates of curbside collection costs have focused on such settings."(EPA,1990) Given the large population residing in urban areas, and the critical shortage of MSW disposal capacity facing many of these areas, additional research into the costs of urban recycling programs is needed.

Section 8. Diversified operation of curbside programs

(i)Operation by charging residents for the services

"One approach that can be used is to fund the recycling program directly from the collection operation by charging residents for the services provided. This can be accomplished in one of two ways. In municipalities that directly bill residents for services, such as solid waste, sewage, electricity, etc., another charge could be added that reflects the cost of providing the recycling service. Only in this case, instead of the municipality being charged, individual residents are billed."(BIO,1990)

"Another version of direct billing is being utilized to pay for a yard waste collection program in Urbana, Illinois. The city is contracting with a private hauler to provide collection services. To pay for the program, biodegradable bags are sold through retail outlets. The costs of the bags, (or ties that are used for brush) are priced to cover the cost of collection. In Urbana's case that cost is $.50 per bag and $2.50 per brush tie."(BIO,1990)

(ii)Operation in urban areas with multi-family dwellings

As pointed out in Section 1 and 3, there are a number of concerns specific to urban areas which may have a significant impact on the net cost of recyclable collection programs (e.g., large population, critical shortage of MSW disposal capacity, difficulty of access for collection vehicles, lack of storage space in many apartments and condominiums, widespread use of dumpsters in urban settings).

The City of Seattle has a population of half a million and in 1987 generated an estimated 686,695 tons of waste. To achieve a 60 percent reduction and recycling goal, the City is implementing a wide range of programs including public education, curbside collection of recyclables and yard waste, commercial and apartment recycling and mixed-waste processing.(BIO,1990)

Waste reduction is the City's highest priority for solid waste management. The most effective waste reduction strategy has been the variable can rate structure which gives customers a financial incentive to reduce the amount of garbage they throw away. Residents must pay for the amount of garbage they produce. As they reduce the amount they set out, they are rewarded by a cheaper garbage bill. Since 1981 when the variable can rate structure was established, the average subscription for residential ratepayers has dropped from 3.5 to 1.4 cans. Multi-family Variable Rates, which is one of the City's new rate structures, are summarized below:

"Multi-family building owners can choose any level of service, whereas previously they were limited to subscription levels equal to multiples of the number of units. Allowing these customers more service level flexibility will provide increased incentive to reduce the volume of waste disposed. In 1988, a full-time apartment recycling coordinator was hired to develop and implement the apartment recycling program. The coordinator is responsible for informing apartment owners, managers and dwellers how to recycle, promoting the availability of the program throughout the City, and coordinating information between the City, recyclers and apartment building owners, managers and tenants. In 1989, the Seattle City Council approved an Apartment Recycling Diversion Credit Program. According to the diversion credit program, the City pays private recyclers for each ton of recyclable material that they divert from the apartment building waste stream."(BIO,1990) The program is seen as a way to provide a variety of recycling services to multi-family buildings.

Section 9. Source separation options

In a curbside collection program, separation may be performed either by residents at home before setting materials out for collecting, or by the MSW collection agency either at curbside or at a central processing facility. Home separation requires residents to make multiple separations, curbside separation requires collectors to sort commingled recyclables into separate compartments at the curbside, and commingled collection requires collection agencies to deliver mixed materials to a designated processing facility.(BIO,1990/EPA,1990)

(1)Intermediate markets

"In some areas of the country, intermediate markets exist that will pay for loads of commingled recyclables - mixed batches of newspaper, color-mixed glass, and metal containers. These intermediate markets were available in New Jersey, for instance, up to 1988. The availability of such markets, however, has decreased or disappeared as market conditions are changing. Most markets that currently purchase recyclable materials require that the commodities be separated."(BIO,1990)

(ii)Home separation

"Sorting of recyclables, if performed at all, may be carried out by residents or by the collection crew. Requiring some sorting to be completed by residents may reduce program costs (both for collection and for additional processing) and increase per-ton revenue from recyclable sales. Most of the long standing recycling programs have relied on residents to do the bulk of the separation in the home. In general, requiring residents to complete at least partial sorting (into two to, at most, four categories of recyclables) appears to be most cost-effective."(EPA,1990)

On the other hand, there are some opposite opinions. This sorting option may increase collection costs, because more sophisticated collection vehicles are required and collecting separated materials is more time consuming than commingled materials.(EPA,1990) The costs associated with purchasing multiple-sort home storage containers (stacking bins, multiple bag systems, can and rack systems, etc.) exceeds the costs of most single container systems for commingled recyclables. In addition, this separation alternative may tend to reduce participation if sorting and storing a number of classes of recyclables becomes a burden on participants.(BIO,1990/EPA,1990) Since residents cannot be relied upon to make perfect sorts every time, some level of quality control will still be required by collectors.(BIO,1990) Thus, a separation option that requires residents to make multiple sorts in home may not be desirable from an economic viewpoint.

Requiring some sorting to be completed by residents may reduce program costs for additional processing and increase per-ton revenue from sales of recyclables. However, for recycling in Japan, these advantages are likely to be overwhelmed by the following disadvantages. This sorting option may increase collection costs, especially in Japan, because more sophisticated collection vehicles are required and collecting separated materials is more time consuming than commingled materials. It is also a problem that since residents cannot be relied upon to make perfect sorts every time, some level of quality control will still be required by collectors. Thus, a separation option requiring residents to make multiple sorts at home may not be desirable in Japan from an economic viewpoint.

(iii)Commingled collection

Commingled collection would involve asking residents to commingle, or mix, recyclables in the home and place them curbside in a single container and then generally require collectors to place paper into one compartment and mixed bottles, cans and plastics into another.(BIO,1990/EPA,1990)

This option is generally believed to maximize public participation because this option will be the least burden on the participants comparing other alternatives. In addition, this option has some clear advantages in terms of route size and vehicle capacity utilization over curbside sort.

"In timing studies conducted in three communities comparing commingling with curbside sorting, the advantages of commingled collection are apparent. Two communities averaged slightly more than 30 seconds per stop with 5 separations at the curb. These same communities reduced time per stop between 7 and 10 seconds with commingled collection (one compartment for paper and another for mixed containers). This time savings resulted in extending route sizes substantially."(BIO,1990)

Another benefit of commingled collection is greater utilization of truck capacity. When a collection truck is divided into four or five compartments, it is difficult to size each compartment so that they all fill up at the same rate. For example, the glass compartment may only be one-third full when the paper compartment is full. This improper ratio of compartment space results in the truck being forced off route with only one compartment full. Trucks using multiple compartments with curbside sort are often forced off route by full paper compartments when total truck capacity is only around 60 percent. With just two compartments, it is much easier to properly locate the divider for maximum utilization of available truck capacity. Better utilization of truck capacity results in fewer trips to the processing/storage facility, less non-productive time, and more efficient collection.(BIO,1990)

Thanks to the time savings and efficient utilization of truck capacity, commingled collection is considered as a cost-effective separation option in Japan because fuel cost, such as LPG and gasoline, is very much higher in the country than the U.S.A.

However, commingled collection may require the development of fairly expensive materials recovery facilities (MRFs), because additional processing for the separation of recyclables from the commingled waste materials after collection and before their sale will always be needed in order to meet market specifications.(BIO,1990/EPA,1990) Further discussion on MRFs will follow in Chapter 8.

(iv)Curbside sort

"It is important for the community to know how the householder must prepare recyclable materials prior to collection, and in how many compartments it wishes the collector to haul these materials. Clearly, it makes no sense to require more elaborate sorting on the part of the household than on the part of the collector. Imagine the disillusionment of households who carefully set out separated cans and bottles and observe a collector loading them willy-nilly into the same compartment. It is possible, however, to require households to place all recyclables in one container and to require the collector to sort into separate bins in the recycling vehicle prior to delivery to the processing plant."(BIO,1990)

Probably the biggest advantage of curbside sorting is in not having to develop and pay to operate expensive processing facilities. For those communities whose operating budgets are more easily increased than their access to capital monies, curbside sorting is an ideal answer to the question of who does the sorting and where. Also, communities whose local intermediate markets are strong but lack extensive processing capacity and therefore require separation are good candidates for curbside sorting. The strategy of curbside sorting enables residents to source separate without worrying about multiple sorting, and it enables the community to sell quality separated materials to markets without installing an extensive processing system. Under such a scenario, mixed materials are placed at the curb by the resident. The collector picks up the home storage container and sorts the materials at the side of the truck into discrete fractions representing the various salable commodities.(BIO,1990)

As curbside sorters separate the materials, they may also perform a quality control function by rejecting non-recyclables (these are simply left in the container). As a result, the separated materials are probably close to market specifications, subject to training and performance of the sorters. For aluminum UBC, because magnetic can separators are usually inexpensive, many intermediate markets have them on site, allowing for a mix of aluminum and ferrous UBC on the collection vehicle.(BIO,1990)

"For those who do not believe that collectors can physically sort at the curb and still complete a respectably sized route, an examination of some of these programs may be enlightening. The contract collector in Anne Arundel County, Maryland, completes routes of slightly over 1,000 homes a day using curbside sort - in a program that is achieving weekly participation rates of 45 to 60 percent. Given the average level of participation, between 450 and 600 stops per day are actually picked up, sorted and loaded into the collection truck. The County facility, which is essentially a storage and transfer point for materials, provides minimal processing. Only mixed cans are magnetically separated before shipment. Caution should be taken in extrapolating these collection rates. The number of achievable stops per day will be community-specific, depending on such things as housing density, participation rates, number of sorts required, type and capacity of vehicle, etc."(BIO,1990)

"There is probably an upper limit to the number of single family homes that can be efficiently collected using curbside sorting as the collection and separation mechanism. Generally, as these programs expand from start-up projects of less than 10,000 homes to tens of thousands of homes, the switch to commingled collection and a processing line is necessitated. One advantage of initially beginning a curbside program with curbside sorting is the fact that the capabilities of the processing method can change as the program grows without changing the separation behaviors of the residents." (BIO,1990) As far as the housing density is concerned, this option will be not effective in large cities, such as Tokyo and Osaka in Japan, because those cities apparently exceed the appropriate upper limit to the number of dwellings.

On the other hand, communities of about 10,000 or fewer stops should carefully consider curbside sorting. It may be all that is needed in terms of processing capacity, and curbside sorting allows quick start-up of pilot projects with minimal capital outlay for processing equipment. Small and medium sized communities should compare the collection efficiencies of commingled collection and a mini MRF with curbside sort and little or no processing.(BIO,1990)

(v)A bag cocollection system

The cocollection system works like this. Residents store recyclables in a single-color coded bag and place the bag alongside the trash for collection. Both the trash and bag of recyclables are placed in the packer truck and transported to a location, such as a transfer station or processing facility, where the bags of recyclables are removed from MSW. The commingled recyclables are then separated and processed for market.(BIO,1990)

One company at the forefront of this technique is Material Recovery and Recycling Corporation (MRRC), an affiliate of Energy Answers Corporation. MRRC has begun to market "Recycle Bag", which can provide a system approach to cocollection. In addition, a Florida company, Plastics Recovery, Inc., recently began to market a cocollection system, "Cyclesac." Plastics Recovery will supply companies and municipalities wishing to set up their own systems with its woven polypropylene bags.(BIO,1990)

Currently, collecting recyclables from the home is almost exclusively done using a dedicated vehicle and crew. It is a system that has been readily accepted by both the collectors and the public alike. Its one drawback is the expense of extra trucks and crews. In the late 1970s and early 1980s, effort was put into devising a system that used a single truck and crew to collect both recyclables and MSW. One approach was to couple a reduced size packer truck for solid waste with a series of storage compartments for recyclables on the same chassis. While this hybrid did not catch on for various reasons, several municipalities did, and continue to, use a trailer attached to a packer truck to collect recyclables.(BIO,1990)

"While cocollection system would eliminate the need for an extra truck and crew, certainly the most expensive part of curbside collection, it has significant drawbacks. First, the system necessitates that some type of facility be developed where the bags of recyclables can be removed from the solid waste. Second, the commingled collection requires that some form of separation of the materials be completed. Additionally, there is a concern about quality of the materials provided by such programs. Glass breakage could average 40 percent or higher, so that alternative markets to glass container manufacturers would be required."(BIO,1990) The broken glass also may cause contamination of the other components, such as aluminum and plastic containers, placed in the bag, and result in decreasing quality of those recyclable materials. Therefore, cocollection system seems not to be an effective source separation method for post-consumer aluminum cans and plastic bottles.

Chapter 4. Container Deposit Legislation

Deposit legislation is now viewed as an option to divert recyclable containers from the MSW stream, although it was originally introduced in the 1970s and implemented as a means to reduce roadside litter. (Schell,1989) Container deposit legislation, the so-called "bottle bills", has been enacted in nine States. "In general, current deposits apply to aluminum cans, PET bottles, and glass containers for soft drink, beer, and some bottled water. None of the current State laws recovers milk jugs, or containers for non-beverage liquids (e.g., bleach, cleaners). Nor do any State laws apply to paperboard containers (e.g., milk cartons)."(EPA,1990)

"Meanwhile, California also has legislation that provides an incentive for consumers to recycle beverage bottles, although not a deposit system. In California, consumers are given a refund (equal to the redemption value) for every container they return. The beverage industry pays the redemption value."(EPA,1990)

Section 1. Advantages and disadvantages

(1)Advantages

First, bottle deposit laws are an important contributor to the high aluminum can recycling rate, with return rates nearing 90 percent in most bottle-bill States.(Alcoa,1987/Henry,1989) The nine bottle-bill States currently account for an estimated 50 percent of the aluminum being recycled in the U.S.A.(Henry,1989) In addition, these States are currently the primary suppliers for the plastic recycling processors. These States currently account for nearly 100 percent of the plastic being recycled in the U.S.A.(EPA,1990/Henry,1989) The recyclable materials, including aluminum, plastic, and glass, collected in these States represent an estimated 25 percent of the nationwide recyclable waste stream.(Henry,1989)

Table 2 presents data on the compliance rates of beverage containers in the bottle-bill States and California, although Connecticut and Delaware are not included. Estimated compliance rates in the bottle-bill States range from 50 to over 90 percent.(EPA,1990)

Table 2 - Estimated return rates of post-consumer beverage containers resulting from bottle bill legislation

State	Year passed	Primary collection method	% Recovery of all containers	% Recovery of targeted plastics(PET)	Deposit minimum (cents)
California	1986	Redemption centers	>53	5	1(b)
Iowa	1979	Retailers	91-95	--	5
Maine	1978	Redemption centers	56	50	5
Massachusetts	1983	Retailers	87-99	60-90	5
Michigan	1978	Retailers	92-93	90	10
New York	1983	Retailers	74	70	5
Oregon	1971	Retailers	95	80-90	5
Vermont	1973	Redemption centers	80-90	65-70	5

(a) These figures are estimates in 1988 and 1989. Many States with bottle bills have no established reporting system or requirements.

(b) The California return incentive increases proportionately depending upon the total amount of scrap collected in the State. Also added is an amount equaling the current scrap value of the container.

Source : EPA, 1990

Second, container deposit legislation has proven to allow collection of homogeneous resin streams because it targets specific categories of plastic containers. Deposit laws provide a guaranteed supply of high quality material, and are very successful at capturing a large proportion of targeted plastic beverage containers, yielding homogeneous recycled resins amenable to high-value processing applications. Deposit legislation as currently enacted (i.e., targeted at only a few classes of plastic containers) has the advantage that it generally yields resins pure enough to feed recycling processes demanding homogeneous resin inputs.(EPA,1990) For clean, homogeneous resins, industrial scrap had been the only major reliable source until recently. However, post-consumer plastics collected under bottle bills, particularly PET soda bottles, succeeded in creating another stable source. Companies such as Wellman, Inc. developed technology markets utilizing these homogeneous, clean resins.(Schell,1989)

Third, this collection option may be appropriate in those States where demographics militate against the widespread use of curbside collection. (EPA,1990) Rural areas with low density of population may not be economically suitable to curbside programs, but seem to succeed in achieving high participation rates with deposit laws.

Fourth, the level of public support in the bottle-bill States is relatively high.(Henry,1989) **Table 3** shows that the level of public support ranges from 78 to 97 percent in these States. It appears that most citizens in these States suffer no inconvenience relevant to returning containers to such collection places as retailers and redemption centers.

Table 3 Level of public support in bottle-bill States

Connecticut	79%
Maine	84%
Massachusetts	78%
Michigan	90%
New York	80%
Oregon	91%
Vermont	97%

Source : Henry,1989

(ii)Disadvantages

First, for plastic recycling, although deposit legislation captures a high percentage of targeted containers, these containers represent only a very small proportion of all plastics in MSW. Container deposit legislation, originally adopted as litter control legislation, will not divert a significant amount of plastic waste. It has been estimated that PET containers, or soft drink containers, usually targeted by most deposit legislation, represent only 3 percent of all plastics in MSW stream, or only 0.2 percent of the entire MSW stream. Deposit legislation, however, typically captures a large percentage of targeted items and yields well-characterized plastics. (EPA,1990)

Since 1972, only nine States have adopted forced deposit laws, the last being New York in 1982. During the same period, the issue was rejected more than 2,000 times in State legislatures and through the referendum process. Rhode Island, the first State with mandatory recycling, rejected container deposit legislation. New Jersey, Florida, and Washington have done the same. A major reason for this rejection is the fact that container deposits address such a small fraction of the overall problem. According to EPA, soft-drink containers, including aluminum and steel/tin cans, plastic and glass bottles, and paper containers, constitute 1.9 percent of all MSW. In addition, these containers combined for all kinds of beverages, not only for soft drinks but also for alcoholic liquors, are less than 5 percent of all MSW.(Stack,1989)

Second, the numbers are equally small for litter. A nationwide survey of litter composition shows that beverage-related litter accounts for little more than 10 percent of total urban litter and no more than 20 percent of litter in rural areas.(Stack,1989/EPA,1990) Littering is an unsightly problem and an offense against the environment that costs taxpayers millions of dollars each year. Bottle bills have failed to significantly reduce litter, largely because beverage containers for beer and soft drinks are only a small fraction of the total litter problem.(FDL,1989) Washington, Nebraska, and Ohio have comprehensive anti-litter laws which address the total spectrum of litter, not just the beverage component. These programs are funded through a self-imposed fee on the retail, beverage, container, fast food, and convenience store industries.(Stack,1989)

Third, some potential exists for conflict between deposit legislation and curbside collection programs (and drop-off recycling centers). For plastics, deposit legislation is generally targeted at easily characterized containers that economically are among the most valuable plastic items in MSW. To the extent that it succeeds in capturing a large proportion of these items, deposit legislation may tend to reduce both the quantity and the economic value of plastics available for curbside collection. This, in turn, may have a negative impact on the costs and benefits of curbside plastic recycling, and may influence some communities to exclude plastics from their recycling programs. Especially if broadened to include additional categories of recyclable plastic items, deposit legislation may tend to adversely impact the viability or success of curbside programs.(EPA,1990)

Fourthly, deposit laws are costly. Deposits are typically 5 cents per container (except in Michigan, where the deposit is 10 cents). State programs may differ in the number of classes of containers covered, the organizational structure enacted to facilitate the return of containers to processors, and the flow of payments to distributors and retailers. There has been significant retail and beverage industry resistance to deposit legislation, however, because of the allegedly high costs to "middlemen" for providing the required collection, storage, and transportation facilities for collected recyclable containers.(EPA,1990) The costs of container deposit legislation are discussed in more detail in Section 3.

Fifthly, forced deposits eliminate thousands of well-paid, skilled jobs. According to the U.S. Department of Commerce, an estimated 82,000 good-paying jobs would be lost if Congress enacted a national beverage container deposit law.(Stack,1989)

Section 2. Beverage industry against bottle bill

For over two decades, the American beverage industry has succeeded in encouraging voluntary recycling of aluminum UBC. The beverage industry has led the nation in developing reclamation technology for its packages, because it strongly believes that recycling, at affordable costs, can reduce reliance on landfills. The soft drink industry opposes mandatory deposit legislation, because bottle bills are an ineffective and terribly simplistic way to approach a complex issue : litter and MSW reduction.(FDL,1989) The following paragraphs are further discussion on the negative side from the standpoint of the beverage industry.

(i)Discriminatory nature of the legislation

Forced container deposit programs at the State or national level run counter to the increasingly apparent need for comprehensive solutions. Based on past experience, bottle bills have proven to be narrow, costly, discriminatory, and ineffective. Recently, various industries opposed to a national container law called on Congress to avoid taking a simplistic approach to the solid waste challenge. They recommended that all contributors to the solid waste stream be involved in the solution. States with effective, comprehensive programs have realized that industry cooperation and participation are key factors for success. Economic incentives for industry, self-developed recycling targets, and programs promoting consumer participation are examples of private-sector involvement. Compare this to deposit laws, where the beverage industry, in particular, is singled out for punitive, restrictive requirements. (Stack,1989)

(ii)Other successful alternatives to forced deposit laws

There clearly are a number of successful, proven and viable alternatives to forced deposits. Thus, the 41 non-bottle-bill States have examined and then rejected deposits in favor of programs that do a better job. They are :

* Anti-littering and recycling laws, which have had a major environmental impact in Washington, Virginia, Ohio, Nebraska, Tennessee and New Jersey.(FDL,1989)
* Beverage Industry Recycling Programs (BIRPs) have been effective forces in voluntary recycling in states including Florida, Kansas, Kentucky, Maryland, New Mexico, Ohio, Oklahoma and West Virginia.(FDL,1989)
* Keep America Beautiful Systems (KAB) have helped numerous localities promote recycling and litter control.(FDL,1989)
* Other industry sponsored recycling programs have made important contributions to litter abatement, including programs in Colorado, Minnesota, Alabama, Delaware, Hawaii, Louisiana, North Carolina, Pennsylvania, Montana and Wisconsin.(FDL,1989/Stack,1989)

Section 3. Costs of container deposit laws

According to research conducted by EPA, enactment and implementation of deposit legislation have frequently aroused controversy because of its purportedly significant economic impact on beverage distributors and retailers.(EPA,1990) On the other hand, the beverage industry argues that deposit laws are economic burdens on it and the bottle-bill States as well,(Stack,1989) although all of the data used in its report seem not always to be up-to-date and as a result the reliability of its argument may be partially inferior to that of the EPA research.

As part of a review of proposed Federal container deposit legislation, EPA has initiated an analysis of the costs and benefits associated with such legislation. The most critical finding in the preliminary results of this analysis is that any costs imposed on distributors and retailers are ultimately passed on to consumers (as increases in beverage prices), and that any such price increases have not had a significant impact on current beverage markets or consumer purchasing patterns.(EPA,1990) In fact, however, beverage sales dropped dramatically when deposit laws were initially implemented. During the first year of the container law, beverage sales fell 9.1 percent in Vermont, 6.8 percent in Maine, 11 percent in Michigan, 10.6 percent in Connecticut, and 7 percent in New York. (Stack,1989) The costs of container deposit laws may fall on three sectors: 1) consumers, 2) retailers, and 3) distributors.(EPA,1990/Stack,1989)

1. Consumers

Consumers bear a number of costs. Although deposits are redeemed when containers are returned to a collection center, consumers incur economic costs related to the time required to return containers and collect deposits. An economic cost may also be attributed to the time and inconvenience associated with container rinsing and storage prior to return. Consumers also ultimately reimburse retailers and distributors for the costs of their contribution to the collection program.(EPA,1990) Without exception, beverage prices have increased between 7 and 26 percent under deposit law.(Stack,1989) In Iowa, for example, retail prices of deposit beverages are estimated to have increased approximately 2 to 3 cents per container, (EPA,1990) and consumers are paying annually between $36 million and $46 million more in beverage prices.(Stack,1989) A New York study calculated that consumer prices have increased an average of 2.4 cents per container for beer and approximately 1 cent per container for soft drinks as the result of deposit legislation. (EPA,1990)

2. Retailers

Retailers also incur a number of costs, primarily in the labor required to provide deposit return services to consumers, the space required to store collected containers, and the administrative overhead associated with the collection program. Although retailers are typically compensated for their services by a per-container payment in excess of the consumer deposit, many retailers and their trade associations in the bottle-bill States claim that these payments do not cover their costs of participation in the deposit redemption program.(EPA,1990)

3. Distributors

Beverage distributors are typically required, in effect, to run the container redemption system - collecting containers from retailers, paying retailers a handling fee, and arranging to market collected containers. If distributors cannot or choose not to sell collected containers to recycling processors (as they apparently sometimes have not, especially with plastic containers), they may also have to bear disposal costs. In some States unredeemed container deposits, which may amount to millions of dollars, are disbursed to distributors to compensate them for the costs of their contribution to deposit programs. Even in these States, however, distributors frequently believe that they are not fully compensated for the costs of managing deposit redemption system. As mentioned above, if retailers and/or distributors believe that they incur a net cost related to their participation in deposit programs, they pass this cost back to consumers in the form of higher beverage prices, although it is difficult to derive accurate estimates of the impact on consumer prices of deposit legislation.(EPA,1990)

In Japan, on the contrary, retail prices of bottled beverage are generally controlled by producers and an identical price is applied to a product being sold in any region. In other words, wholesalers and retailers have no choice in determining the selling price of bottled beverages including beer and soft drinks so that consumers can buy a bottled beverage for the same price across the country.

Section 4. Interaction of bottle bill and curbside collection

As mentioned in Section 1, among the most important recycling alternatives, the major potential interaction appears to concern curbside collection and bottle deposit legislation, i.e., the potential of deposit legislation to remove the highest-value recyclables from the recycling stream and thus adversely affect the economics of curbside collection programs, which tend not to collect large quantities of supply-limited materials.(EPA,1990/Stack,1989) The economic contribution of beverage containers to curbside collection is significant. "While beverage containers are less than 18 percent of household recyclables, they generate 49 percent of the revenue source. Recyclers often refer to these containers as the "gold" of the waste stream."(Stack,1989)

On the other hand, several of the successful so-called curbside States that are mentioned in various studies are, in fact, bottle-bill States as well, and have no intention of choosing between the two systems. Comprehensive recycling programs, including curbside, drop-off centers, etc., and deposit laws are not mutually exclusive in Connecticut, New York, Oregon, and Michigan. For example, Michigan's deposit law will, by the end of the Nineties, be funding comprehensive recycling programs to the tune of $50 million annually through the state's unclaimed deposit fund. An Anheuser-Busch study in 1989 revealed that a recycling program combining a curbside and a deposit recovers over 40 percent more materials than a sole curbside program in Vermont. Likewise, it projected that New York State would recover 16 percent more with a combined program.(Henry,1989)

It would be more expensive for a State to operate both a deposit and a curbside program than the curbside system alone. However, combination of a bottle bill and a curbside program seems to have advantageous features that compensate for inferiorities of one collection option with superiorities of the other option.

The bottle bill is inferior to curbside pickup in terms of convenience to participants. "Deposit supporters often cite the high container recovery rates under a bottle bill. However, in some deposit States the redemption rate is actually decreasing. When offered the convenience of curbside pick-up for household recyclables, homeowners are opting to place deposit containers at the curb rather hauling them to a retail store. Some curbside collection programs in New York and Connecticut reportedly have container volumes consisting of 20 to 25 percent deposit bottles and cans. Such figures indicate that consumers prefer convenience and comprehensive recycling, both lacking under a deposit system."(Stack,1989) Homeowners should be supportive of a single recovery system. Under deposits, beverage containers must be taken to one location, while other recyclables are taken to another location.

Section 5. Limited experience for deposit laws in Japan

Most municipalities have separated flammable materials, such as paper and plastics, from non-flammables in MSW stream, and then landfilled the non-flammable wastes, including steel and aluminum cans, batteries, glass, and so on. Localities that landfill aluminum UBC explain that they cannot afford to pay high separation fees regarding recyclables in waste streams. In addition, they have no responsibilities for aluminum and plastic container recycling because such legislation and laws as bottle bills enacted in the U.S.A. do not exist in Japan. In that country, in fact, such deposit laws have been applied to only glass bottles particularly used for beer.

Chapter 5. Reverse-Vending Machines

Section 1. Structure of reverse-vending machines

A single machine accepts a specific class (or a few classes) of containers upon verifying they are the proper type, and then issues the customer either cash, a reduced-price coupon for a subsequent purchase, or a receipt redeemable for either cash or merchandise. Most machines incorporate a compactor or shredder to minimize internal storage requirements for the recycled material.(Alcoa,1987/EPA,1990)

For metals, the machines can be designed to accept aluminum cans only, or to take both aluminum and bimetallic cans. Machines can accept up to 35 containers per minute, crush them and drop the crushed cans into a bin. Laser scanners to read the UPC code have been incorporated in some models, which are capable of printing out reports of accepted containers by brand name, size, etc. Other machines function by shape recognition.(Alcoa,1987)

For plastics, reverse-vending machines can allow discrimination between resin types. Feasible technologies exist that can allow these machines to differentiate among resins, either to limit the plastics accepted or to sort plastics for processing. Current use of these machines has been largely limited to PET containers for soft drinks. PET machines are designed to either shred or to puncture and crush the plastic bottles. However, the technology may be applied to other plastic containers for milk and laundry detergent.(EPA,1990)

Section 2. Advantageous features

The primary advantage of reverse-vending machines is that they require no human involvement at the point of recycling. Therefore, they can be widely distributed, for example, at supermarkets and other retail outlets. They seem to be increasing in popularity in the U.S.A.(Alcoa,1987/EPA,1990)

On the other hand, these machines are not an independent option for collection, but an supplementary option available to support non-curbside collection programs, including drop-off recycling centers, voluntary buy-back programs, and container deposit legislation. These machines can greatly increase the convenience of consumer participation in these collection alternatives other than curbside programs. However, they are particularly attractive as a collection option in support of container deposit laws because they reduce the cost, space, and manpower requirements associated with collection of recyclables by retailers or other collection centers. These machines are currently being deployed in at least three bottle-bill States (Connecticut, New York, and Massachusetts) and have been legally recognized as recycling centers under California's recycling program.(EPA,1990)

PART TWO
IMPORTANT ELEMENTS COMMON TO ALL COLLECTION METHODS

This part is comprised of two chapters. One is strategies to increase citizen participation and the other is enforcement of mandatory ordinances. Both of these two chapters are related to all of the alternative collection methods that are discussed in Part One. Citizen participation in collection programs is a key factor to success of the entire recycling system. In order to enhance the effectiveness of a collection program in a municipality, it is also of importance to monitor and enforce public participation in compliance with mandatory ordinances of the municipality.

Chapter 6. Strategies to increase citizen participation

Recycling programs in many communities grew from the grassroots with support of citizens, environmentalists and organizations, and typically require citizens to change their waste disposal behavior. It is obvious that the public cannot and will not adopt a new behavior or participate in a new program unless they know about it, are persuaded of its benefits, find it easy to do, and are frequently reminded to do it.(BIO,1990/Folz & Hazlett,1990) Communities that place more importance on the involvement of citizens and consider their opinions in recycling program design may have higher rates of participation in the actual recycling program.(Folz & Hazlett,1990) The following discussion will focus on public education and incentives for increasing public's participation in recycling programs.

Section 1. Public education strategies

In order to maximize public participation in recycling programs, it is necessary for a community to initiate and continue with an education program. Citizen participation in recycling efforts will be tremendously enhanced by citizen understanding of the importance of recycling efforts to their communities and eventually themselves. The education of individual citizens (and especially those charged with formulating policies and laws) should be concerned with the MSW and litter problems and their roles in coping with these problems on the long-term basis.(BIO,1990/Selke,1988) The education programs may take a variety of forms, including either tangible or intangible, but the direct contact between the collector of recyclable materials and the generator of those materials is usually a key component.(BIO,1990/Polk,1991)

It appears that citizens are best educated about recycling through the use of pamphlets, brochures or bumper stickers, which are often included in utility bill mailouts. Neighborhood or community information meetings, paid newspaper advertisements and speeches by local government officials to schools and local groups about recycling are also used by cities that have higher participation rates. On the other hand, some communities with lower participation rates have used paid radio commercials and billboard advertisements.(Folz & Hazlett,1990)

Section 2. Effectiveness of public information campaigns

An example of a successful recycling program, which includes a public information campaign, operated by local government may help in understanding a comprehensive education program.

Islip, New York, has a population of 306,000, spread over 98 square miles, with 78,000 residences (mainly single-family homes) and 6,000 businesses. In 1988, its solid waste facilities received 390,000 tons of trash. That total included all recyclables. Residential sources accounted for 55 percent of the total waste and non-residential (including schools, government facilities, commercially-serviced apartment buildings, and roadside cleanups) accounted for 45 percent.(BIO,1990)

Islip began a source separation program called WRAP in 1980. Initially the acronym stood for "With Recycling, Alternatives are Possible". The original program required residents to place out for separate collection glass, metal and newspaper commingled in one can.(BIO,1990)

"The key to the town's success has been a simple, uniform collection system combined with an innovative and comprehensive education program. Paramount to the success of the program is the effectiveness of the public information campaign."(BIO,1990) The town early recognized the vital link between public policy and public education and embarked on a campaign that includes :

1) Weekly WRAP Contest : Weekly, 20 names are randomly selected through a computer-generate list of homeowners. WRAP inspectors visit the homes to investigate recycling compliance. If the first homeowner is WRAPing, they win dinner for two (donated by a local radio station). However, if the homeowners are not participating, they are left a notice of prize eligibility that states the WRAP inspectors will be back within 60 days to reinspect and the residents will win a second place prize (an official recycling T-shirt; glass WRAP mug, magnets, pencils, etc.), if they are participating at that time. Since not everyone has sufficient amounts of recyclables each week or people may be ill, on vacation, or forget to put their recyclables out, the town goes back and checks their garbage. If there is heavy evidence of glass, metal and paper contained therein, the inspector has the right to issue a summons. After issuing less than a dozen summonses in 1987, it has not been necessary to issue any more.(BIO,1990)

2) Office of Recycling : An entire new division of the Department of Environmental Control was established to take charge and provide recycling initiatives. The office has been staffed with a Director, Recycling Inspectors with WRAP vehicles that are highly visible throughout the town, a Recycling Coordinator who is responsible for overseeing all projects and maintaining a high public profile, and a Recycling Educator whose chief responsibility is to teach all school children the basics of recycling and to create and maintain a community outreach program.(BIO,1990)

3) Educational Curriculum : "WRAP Sessions" is a series of class lessons designed to instruct and inform grades K-6 on the necessity of sound solid waste practices and policies.(BIO,1990)

4) Public Service Announcements : Intensive news releases are required to keep the public informed on the progress of programs and to explain any changes. A quarterly newsletter is sent out to all residents with WRAP updates. Local radio and TV public service announcements are part of its ongoing campaign.(BIO,1990)

5) WRAP Hotline : A special telephone line has been created for residents to obtain up-to-date information.(BIO,1990)

6) Recycling Advisory Committee : This committee of nationally and locally renowned recycling experts was formed for the express purpose of networking ideas and principles of solid waste practices. The committee provides objective initiatives to further the town's efforts.(BIO,1990)

Section 3. Education concerning the benefits of recycling

The case of New York State is commented on in the following paragraphs as an actual example for public education.

According to New York State Department of Environmental Conservation (DEC), the State will provide education materials on solid waste disposal costs and the environmental and economic benefits of recycling.(NYS,1988)

"At the school level, the New York State Department of Education will be asked to develop infusion materials (education materials that can be meshed with regular classroom work) for coursework in grades K-12. The materials will describe the importance of environmental and resource conservation, especially recycling and reuse. These educational materials may be in place in 1990. The State will publish newsletters such as the DEC Wasteline newsletter, news articles and technical reports highlighting the actual environmental, economic and social costs of waste disposal methods that compete with recycling. Such publications would discuss the economic benefits of increased recycling and the extent of the State and local government support for municipal waste recycling."(NYS,1988)

Other rationales for increased recycling will be brought before the public. For example, the compatibility of source separation with waste-to-energy incineration will be discussed. "Promoters of waste-to-energy technology have come to realize the value of recycling glass and metal to save the wear and tear on equipment. In addition, removing these non-combustibles from the waste raises the heat (BTU) value and potentially reduces the amount of toxics in air emissions and the ash residue to be landfilled. The degree of removal of combustibles expected to occur as a result of recycling is not expected to have a significant effect on the BTU value of the waste stream." (NYS,1988)

Chapter 7. Enforcement of mandatory ordinances

Section 1. Basic elements in drafting mandatory ordinances

Once basic elements of a recycling program have been established, a municipality can begin drafting the ordinance. The key provisions of the ordinance will describe central operative elements which will vary according to the type of recycling program selected by the municipality. However, every recycling ordinance should include certain elements which will be necessary regardless of the type of program developed.(BIO,1990) These include the following:

1. Rulemaking "If the public entity that will implement the ordinance has the power to do so, the ordinance should provide the authority to adopt rules and regulations. This will maximize flexibility and will allow for measures such as phasing in and out various recyclable materials."(BIO,1990)

2. Notice and public education "Each ordinance should require that certain measures be taken for periodic notification of the requirements of the ordinance and for public education. As described earlier, no recycling program can survive without an informed and motivated public."(BIO,1990)

3. Preparation of recyclables "The ordinance should establish standards for the preparation of recyclables for curbside collection or dropoff. It should specify the type and amount of cleaning, the location at which the recyclables should be placed and the extent to which materials may be mixed or segregated."(BIO,1990)

4. Anti-scavenging "Every recycling ordinance should provide an anti-scavenging provision. Those not required or entitled to pick up recyclables from a dropoff center or from the curbside should be forbidden to do so."(BIO,1990)

5. Existing recycling operations and contracts "The ordinance should further include provisions addressing existing contracts and existing recycling operations. The ordinance should provide that it will not interfere with the terms of the contracts executed before its effective date, so as to preserve its constitutionality. However, in an effort to assure that implementation will not be hindered, it should further require that any new contracts or contract renewals be consistent with its provisions. The ordinance may also seek to preserve the ongoing operation of recycling programs already established by non-profit organizations."(BIO,1990)

6. Enforcement "Every ordinance must include provisions to assure enforcement. The ordinance should designate unlawful activities and allow for injunctive relief. It should also establish penalties in an amount consistent with the municipality's authority under the law. If authorized, the ordinance should provide that each continuing day of violation will be deemed a separate violation. The ordinance can include provisions that will discourage noncompliance in other ways, such as a prohibition of collection of trash including recyclable materials that should have been separated." (BIO,1990)

Section 2. Enforcement procedures

(1)Effects of the enforcement on public participation

In general, while the majority of people will recycle if they are informed about the program and it is made convenient for them, there are still many people who will find some excuse for not taking part. In order to involve those people who are not participating in recycling programs, enforcement of mandatory recycling ordinances will be of importance. The enforcement may help implement recycling programs more effectively than just passing the ordinance. While passing it helps establish its legitimacy at the outset, enforcement shows citizens the municipality is seriously sustaining the recycling programs.(BIO,1990)

The communities listed below have all made conscious decisions to monitor and enforce mandatory ordinances (see **Table 4**). They apparently succeed in increasing public participation rates.

Table 4 - Participation rates of municipalities that monitor and enforce mandatory ordinances

Municipality	Participation Rate
Evesham, NJ	90%
Haddonfield, NJ	95%
Hamburg, NY	98%
Islip, NY	90-95%
Prairie Du Sac, WI	97%
Vineland, NJ	85%

Source : BIO,1990

"Enforcement procedures also help to educate the public, not those who want to recycle, but those who need a little extra push. One example of what an effective enforcement program can do is illustrated in Islip, New York. Islip developed a mandatory recycling program in the early 1980's that met with a fair amount of success. At that time, it was probably the largest mandatory program in the U.S.A. Participation at first was estimated to be close to 50 percent, but as the program matured participation declined, reaching by some estimates 30 to 35 percent by 1987. After evaluation, the town decided to upgrade its enforcement efforts as part of a package aimed at increasing participation. The results have been spectacular, with participation now estimated at 90 to 95 percent."(BIO,1990)

(ii)Monitoring process

"The most basic question in ordinance enforcement is how to determine if a person or business is recycling. In most cases, the answer may be to look in the trash. For residential collections, communities either perform a random check of trash containers or rely on the garbage collectors to monitor the trash. Most communities start the monitoring process by checking on the trash set out, but in Islip the first check is on the recycling container. If a house does not have a container out when the area is checked, it is noted by an inspector and the next trash day that residence's trash is checked for recyclables. While enforcement emphasis is generally on trash containing recyclables, communities also are concerned that the recyclables are prepared properly."(BIO,1990)

"Responsibility for enforcing a mandatory ordinance ultimately rests with the municipality, with either the collector of the recyclables/trash or an inspector performing the monitoring function. Where trash containers are inspected, the collection crews would be the obvious choice to complete the work. And when municipal crews do the pickups they usually do the policing. Although the inspection may slow the collection process, in most cases it is not a major time consumer."(BIO,1990)

However, when private crews collect the trash, particularly when they contract directly with homeowners, things are not quite so simple. The National Solid Waste Management Association (NSWMA) has suggested to its members that they work with communities on enforcement and do everything they are willing to do to help make a program successful. Some companies will be more than willing to help. Some will view including enforcement in their programs as a marketing tool and will help, while others would prefer that the municipalities handle the job. They believe that private haulers can provide monitoring services as part of a full service collection package and also are willing to work with municipalities in monitoring compliance, but do not want to get involved in the actual enforcement.(BIO,1990)

"An alternative to using the collectors to perform monitoring activities is to utilize enforcement officers. While it is not likely the municipality's police department will be saddled with the task, in some places municipal code enforcement officers have been used. Vineland and Woodburg, New Jersey, have hired a full time recycling enforcement officer. Islip uses its eight existing code enforcement officers to monitor participation. Inspectors are also being used at transfer stations and landfills to inspect loads (particularly commercial loads) for recyclables and identify the offenders so that they can be notified."(BIO,1990)

(iii)Stepped approach to enforcement

Even with an ordinance in place, most municipalities still place heavy emphasis on education prior to taking any type of enforcement action. For instance, in Evesham Township, New Jersey, when persons are found not to be recycling they are sent a letter informing them of the program and are provided information on how to become involved.(BIO,1990)

"The first action against a non-recycler in many cases is to leave their garbage behind with a note attached explaining the reason. The same is true for those who do not prepare the recyclables properly. In some instances, the notice also states that the person is in violation of the municipal ordinance."(BIO,1990)

"A stepped approach to enforcement is usually followed - first educating, next warning (in many cases, several times), and finally taking enforcement action. At the first violation, the trash collection crew places a tag on the trash container and provides the township manager with a copy to track the monitoring actions. If the problem is not corrected the second week, the container is again tagged and a sanitation supervisor makes a site visit. Should the problem continue, the person can be summoned at that point. The idea of summoning and fining citizens for not recycling is something that most municipalities would like to avoid. In fact, even in those communities that actively monitor compliance, few have ever had to resort to summons and fines."(BIO,1990)

PART THREE
PROCESSING AND MARKETING

After collection activities of recyclable materials are accomplished, the next stages for recycling systems are processing and marketing the materials. Since separation can be done either before collection or after collection, it is not mentioned only in Chapter 3 (curbside collection) but also in this part. For secondary raw materials to be an effective alternative to virgin raw materials, the following conditions need to be met through processing and marketing : 1) Uniform quality and 2) Reliable future cost.

1. Uniform quality

Once the recycling structure is established, it becomes vitally important for success in marketing strategy to consistently maintain reliable quality of the materials collected. Lots of communities and hauling and recycling companies have recognized this and have installed sorting and high-grading facilities, such as materials processing facilities (MRFs).(BIO,1990)

2. Stable cost

The secondary commodity market, particularly aluminum UBC, has been accustomed to wide market fluctuations. However, the price swings must be less volatile, if recycling is to play a more important part in manufacturing processes. In the future, raw material prices will be determined based on avoided waste disposal costs besides supply and demand. The supply of post-consumer recyclable materials will continue to be generated as long as these market prices are greater than the avoided disposal costs.(BIO,1990/EPA,1990)

Chapter 8. Processing Activities

Processing includes a variety of activities, including sorting (e.g., by color of glass), grinding or shredding, and baling of recyclables for sale. (EPA,1990) Major equipment used to process secondary materials at processing facility is as follows : a glass crusher, a can crusher, a platform scale, a vertical and horizontal baler, a surge bin, a slider belt conveyor, a magnetic separator, and several assorted storage containers.(BIO,1990)

Section 1. Source separation

Source separation is the removal of recyclable materials from household, office and business wastes. Sorting of recyclables, if performed at all, may be carried out by residents or by collection crews. If recyclables are not sorted, they will require additional processing before their sale. Separating materials at the source, before the materials mix with other MSW, can ensure that the recovered materials will be relatively clean and of high quality with relatively little contamination.(EPA,1990/NYS,1988)

Source separation is primarily the responsibility of the consumer (waste generator). However, in terms of the public participation, the separation programs tend to be the most successful when consumers are asked to separate to the minimum extent,(BIO,1990/Selke,1988) although there is a study showing that the average participating household spends about 69 minutes each month, or only two minutes a day, separating and bundling glass, metals and newspapers.(NYS,1988)

Section 2. Densification at early stage

A densifying process may involve such equipment as glass crushers, newspaper balers, can flatteners, grinders, shredders, and so forth. For post-consumer aluminum and plastic wastes, the first processing step is typically some type of densification. Both aluminum cans and plastic bottles have a high ratio of volume/weight, or a low density, particularly for plastics, compared with other recyclable constituents of MSW (e.g., steel, tin, and glass). This fact adversely affects the practicality of aluminum and plastic collection in entire recycling systems and the economics of transporting collected materials to processors. If the distance to markets is considerable, then a densifying process may be economically justified. Densification at an early stage is essential to the overall economics of recycling programs.(BIO,1990/EPA,1990/Selke,1988) However, for plastics, shredding and grinding processes result in reducing the practicality of separation into homogeneous resins.(EPA,1990)

Section 3. Intermediate processing

Recovered materials must be prepared for their markets by intermediate processors such as traditional scrap dealers, paper brokers, and beverage container recycling operations. A municipality can also take on some of the activities of an intermediate processor.(NYS,1988)

"Intermediate processing can be done manually or mechanically. For source-separated materials, manual processing separates glass by color, newspaper from glossy paper, plastics by resin type, and aluminum from steel cans. For non-source-separated materials, manual processing removes contaminants such as ceramics, stones, flower pots, toys, junk mail, and medium sized objects."(NYS,1988)

Mechanical processing can be used for both source and non-source separated materials. Magnetic separators remove ferrous metals which, depending on the waste stream from which they are removed, may be marketable without further processing. Blowers or vacuums separate the lighter portion, such as paper and plastics, and air classification or screening removes glass from the remaining waste stream. Finally, a baler, shredder, or crusher is used to compact the material for shipping. (BIO,1990/NYS,1988)

Section 4. Costs of processing recyclables

Processing imposes both capital and operating costs on a recycling program. Its primary economic benefit lies in the increased sales value of the recycled materials. Another benefit may accrue if a minimal sorting requirement acts to increase participation rates and/or the volume recycled per participant.(BIO,1990/EPA,1990) Additional economics (expressed as increased sales revenues) may accrue because of the cooperative marketing and large sales volumes allowed by a regional processing center. These economics will be reduced by increased operating expenses associated with the time and labor required to transport recyclables to a remote processing facility.(BIO,1990)

"Costs of processing recyclables are greatly determined by how closely residents' sorting of materials and the locality's separated collection matches the categories for which markets are available. For example, if residents place newspapers separately for collection, and these are collected in a dedicated container, then processing simply requires spot removal of contaminants and baling. However, if newspapers, cans and bottles are all presented together for collection, a manual/mechanical sorting will be necessary in order to remove the newsprint from the mixed recyclables prior to baling."(BIO,1990)

"Processing costs will increase dramatically with the number of manual sorts which must be made. To a somewhat lesser extent, processing costs increase with the the number of mechanical sorts (separation of aluminum cans from other cans and bottles, e.g.) required. These costs are greatly determined by how closely residents' sorting of materials and the locality's separated collection matches the categories for which markets are available. Of course, it is uneconomic to sort or process recyclables if the extra cost of the sorting operation does not exceed the extra revenue expected from the processed waste. While this may seem an obvious observation, it is one worth remembering and one worth computing before constructing processing plants. A well-planned recycling program considers alternatives for pre-collection sorting and the impact of such alternatives on processing costs and on revenues. Whenever pre-collection sorting can feasibly be substituted for post-collection processing, the economic viability of the system will usually be improved."(BIO,1990)

Municipalities are increasingly forced into waste management which is more capital-intensive than landfilling, such as recycling and composting. Processing facilities may be most economical if implemented as county or regional centers serving a number of municipalities because of their capital costs. In order to support the financing of such facilities, it is essential that the municipality be able to guarantee delivery of consistent amounts of solid waste.(BIO,1990/EPA,1990)

Section 5. Materials recovery facilities

A materials recovery facility (MRF) is basically designed to separate commingled recyclables and then process the separated materials into marketable commodities. MRFs are a relatively new development in the MSW recycling field. The first MRF was begun as a research and development project in 1975 by Resource Recovery Systems. In the early 1980s, the company launched the first fullscale MRF at Groton, Connecticut, and a publicly owned and operated facility followed in Islip, New York.(BIO,1990)

(i)Benefits of MRFs connected with commingled collection

As mentioned in Chapter 3, commingled collection may require MRFs, because it will always need additional processing for the separation of recyclables from the commingled materials after collection in order to meet market specifications. For source separation in curbside collection programs, MRFs require not curbside sorting but commingled collection. Equipment for commingled collection can be more simple than that for curbside separation. For example, vehicles for commingled collection need fewer compartments than those for curbside sorting. Times and costs required for putting commingled recyclables into one or two compartments at curbside and then emptying them at recycling centers can be much less than those for sorting and putting recyclables into five or six compartments and then emptying them.

In addition, for quality of the recycled materials, processing through a MRF can produce more marketable materials, which exactly meet industry standards, than manual sorting.(BIO,1990)

(ii)Separating procedure

"Separating the mixed bottles and cans is the heart of a MRF. In most of the systems, steel cans are pulled from the mixed materials first by using a magnet. After the steel cans are removed, the remainders are glass, aluminum, and in some cases plastics. At this point in the process, the mechanical systems utilize either air classification or inclined sorting equipment to separate the lighter fraction, the aluminum and plastics, from the glass. After the glass bottles are separated, the aluminum is separated from the plastics, either manually or with aluminum separating equipment such as eddy current separators."(BIO,1990)

While theoretically, almost 100 percent of the materials coming into a MRF can be recycled, all systems actually produce a residue, ranging from less than 1 percent to more than 20 percent of input. If residents dispose of non-recyclables through the system, understandably the amount of residue increases.(BIO,1990)

(iii)Capital and operating cost for mechanical and manual systems

The trade-off between the manual and mechanical MRFs is capital versus operating cost. Manual operations can process about six tons/day for every worker. Mechanical systems claim a processing capability of about ten tons per worker. The workers include operating personnel and support staff. The capital cost of equipment for the mechanical systems ranges from 75 to 100 percent higher than the manual systems.(BIO,1990)

(iv)Cost range of MRF

"Separation facilities or MRFs can be multimillion dollar installations with sophisticated trommels, balers, conveyors and air classifiers, or simple hand-picking conveyor lines and magnetic separators. Some communities have developed small MRFs or mini MRFs, for less than $100,000. If an existing building is available, a small picking conveyor with a submerged feed conveyor may only cost $25,000 to $35,000. Program sponsors must carefully consider market specifications and projected quantities when considering processing equipment."(BIO,1990)

The cost of separating commingled loads does not have to be in the millions of dollars when relatively small quantities are involved. Operating cost for mini MRFs can be reasonable. Some mini MRFs only use two people for labor. If collection rates are small enough to allow time at the end of the day, or if collection does not occur every day, a mini MRF could be operated by the same people doing the collection.(BIO,1990) Therefore, mini MRFs seem to be suitable to rural areas with a low population density.

Chapter 9. Marketing

It is obvious in the recycling field that markets for collected materials are the foundation for any program. The recycling level will depend on having readily available markets for recycled products. Although the increases in waste disposal costs have favorably altered the economics of recycling in the U.S.A., many firms remain dependent on revenues from sale of recyclable materials. Governments at all levels have a responsibility not only to establish programs to separate and collect materials from the waste stream, but also to create new and expanded markets so that the materials can be used to manufacture new products.(BIO,1990/Keller,1989)

Section 1. Federal efforts for market development

Two major sections of the Resource Conservation and Recovery Act (RCRA) establish a federal role in creating markets for recyclables.

"Section 5003 requires the Department of Commerce to identify the geographical location of existing markets for recovered materials, to identify economic and technical barriers to the use of recovered materials, and to encourage the development of new use for recovered materials. To date, Commerce has not done nearly enough to expand markets for recyclables."(Keller,1989)

The Department of Commerce needs to consider a variety of actions to expand markets for recycling. These would include :

* providing technical and financial assistance to State, local and regional organizations for market development studies;
* assisting State, local and regional development agencies in attracting new recycling businesses and helping existing businesses to use more recovered materials;
* determining incentives needed for establishing manufacturing facilities which use recycled products, such as deinking facilities;
* setting standards for recycled products, such as compost;
* identifying alternative uses for products such as newsprint;
* testing recycled products such as mixed plastics; and
* collecting and disseminating data on programs, such as affirmative procurement.(Keller,1989)

"Section 6002 of the RCRA requires the U.S. EPA to prepare, and from time to time revise, guidelines for procuring agencies to buy items composed of the highest percentage of recovered materials practicable. The guideline applies to federal agencies, and to State and local agencies and their contractors using appropriated federal funds. RCRA also requires all procuring agencies to develop an affirmative procurement program which will assure that items composed of recovered materials will be purchased to the maximum extent practicable."(Keller,1989)

In the Nineties, this program's major goal must be to ensure that all federal agencies comply with the guideline. Federal purchases represent about 7 to 8 percent of GNP, although the percentage varies from product to product, and would result in affecting the markets for recycled products. The more important aspect of the guideline is that federal purchases can be used as a model by State, local, and private agencies to establish similar programs and expand the market even further.(Keller,1989)

RCRA states that an agency may decide not to buy a recycled product if the price is unreasonable. In addition, EPA's guideline, which determined that an unreasonable price is any price greater than the lowest comparable virgin prices, was recently upheld by the U.S. Court of Appeals. As a result, it will be difficult for recycled products to obtain a strong footing in the marketplace without any price preference for them. Because the prices of the recovered products are frequently fluctuating, they may happen to become more expensive than the lowest prices of comparable virgin products. Therefore, Congress must clarify the requirements regarding a price preference for recycled products.(Keller,1989)

Section 2. Efforts by State and local governments

On the whole, both State and local governments need to expand and refine their traditional and current roles in MSW management to solve the complex problem that faces them and to develop recycling systems as a whole. (NYS,1988)

(1)Economic development programs and agencies

States have traditionally had economic development programs to encourage industrial expansion. Such programs have long relied on tax credits, low-interest loans and other inducements to aid industry. The existence of these general economic development programs alone can be a great aid to the recycling industry.(BIO,1990) The recycling industry must work closely with State and local economic development agencies to ensure that it receives assistance (both economic and technical) in expanding their use of recycled materials. The economic development agencies, which are designed to provide incentives to attract new businesses and to help existing businesses to expand, can offer tax incentives, financial benefits, siting and zoning assistance, and other advantages for new or existing businesses. (Keller,1989)

(ii)Tax credits

The New York State government and DEC believe that they should encourage market development and promote use of recycled materials through the legislative proposals such as the following tax incentives :

* Development of tax incentives and tax equity for investing in equipment for the recovery of resources in manufacturing.
* Using available programs to provide grants, low interest loans, and tax incentives to encourage local government and private-sector recycling.
* Development of tax incentives and tax equity for using recovered materials, for example, recovered resources in manufacturing.(NYS,1988)

In addition, Oregon has two programs that ensure substantial tax credits for recycling facilities; one allows a 50 percent credit (taken 5 percent per year over 10 years) and the other a 35 percent credit (taken 10 percent per year over the first two years and 5 percent for the next three years). New Jersey has similar tax-credit programs for recycling facilities.. Its program, which became law in 1987, allows companies to claim a 50 percent tax credit (10 percent per year over five years) for equipment used to manufacture products that contain at least 50 percent post-consumer waste as well as for transportation equipment.(BIO,1990)

On the other hand, as for the tax incentives for utilization of recycled materials, there are some States' opinions other than New York on the negative side. For example, "the Illinois study concentrates on analyzing the impact that various tax incentives would have on the utilization of recycled materials. The study concluded that, given Illinois' tax structure, any tax incentives would have little noticeable effect on the recycling markets. The study also concluded that the cost of recovering additional materials from the waste stream by way of tax incentives would be in the range of $500 and $1,000/ton. In a survey conducted for the Illinois Tax Incentive Study, most recipients said the credits favorably affected the decision to develop the project, although some viewed the credit as a bonus and would have gone through with the project without it."(BIO,1990)

It appears that the conclusions of Illinois study are very negative to the effects of tax incentives on market expansion for recycled materials, in contrast with New York State's official report. Therefore, the effects of tax credits on development of recycling programs appear to be unclear. It seems to be difficult for governments and communities to determine what types of tax incentives should be developed for encouraging use of recovered materials and investment in recycling systems.

(iii)Encouraging use of demand-limited materials

Most efforts by State and local agencies have focused on collecting recyclable materials. For recycling to prosper, however, it is necessary to place a greater emphasis on creating reliable markets for recycled products, particularly demand-limited ones. For example, the market for newspaper does not currently have the capacity enough to absorb all newspapers being collected. In addition, in rural areas, the markets for recycled goods may not easily be able to absorb their rapidly increasing quantities. Therefore, State and local governments must establish additional businesses able to process recyclables and create new products in order to expand the markets, for recycled products to absorb large volumes of recyclables that would be diverted from the solid waste stream.(NYS,1988/Henry,1989/Keller,1989)

For example, New York State encourages use of secondary materials by promoting environmental and economic benefits of recycling through a public education program and legislative initiatives which include :

* Increasing the price preference for recycled products in competitive bidding;
* Requiring contractors doing business with State and local governments to use products made from recovered materials in at least 25 percent of procurement; and
* Providing incentives for investment in recycling systems.(NYS,1988)

(iv)Market studies conducted by States

In 1981 and 1982, California conducted its recycled-material market development study. Michigan undertook market development study in 1986, and Illinois followed shortly thereafter. Since the completion of the two State studies, New Jersey and Pennsylvania have begun studies.(BIO,1990)

According to Michigan's study, which looks at the effects of both supply and demand side stimulants, there is a broad range of impediments to market expansion for the different types of materials and no one incentive will overcome the impediments. For instance, incentives to stimulate plastic recycling are quite different from what is needed to stimulate paper mills to utilize more waste paper.(BIO,1990)

(v)Procurement activities

For procurement of products made from recycled materials, while many States have procurement legislation, those laws primarily targeted paper until recently. Now legislation is recognizing the need to procure more than paper. State and local agencies must augment their purchases of recycled products.(BIO,1990/Keller,1989) For example, New York State will encourage expansion of the markets for recycled materials by expanding State agency procurement practices; providing a series of tax and related financial incentives to businesses; and removing existing discrimination against the purchase and use of secondary materials.(NYS,1988)

On the other hand, while the number of programs is steadily increasing, there is still a great deal that needs to be done to expand actual purchases of recycled products. State, local and regional agencies must establish consistent definitions and minimum content standards to permit manufacturers to make one consistent product for the entire nation, instead of making 50 different products for all the states and over 83,000 products to meet the needs of local governments.(Keller,1989)

(vi)Opening of accumulated data on recycling

State and local governments must keep all records on their programs and share the results of their efforts with other governments so that successful programs can be duplicated and any mistakes not be repeated.(Keller,1989)

In New York State, DEC established a data base in 1989, which can be updated for recyclable materials, materials projected to become recyclable, and for current New York markets. The State will also coordinate with neighboring States to maintain current data on regional market surveys and information from local and neighboring statewide solid waste plans. Data will include collected tonnages of recyclables and an assessment of market demand for specific recovered materials.(NYS,1988)

Section 3. Market for secondary materials

It is of importance to become familiar with the market for secondary materials, from an economic viewpoint, so that economic incentives or disincentives can be used as effective tools for development of the market.

(i)Product definition

There are several dimensions of a definition that need to be examined for each secondary market. One is the definition of the recycled commodity itself and these definitions can easily be obtained from the affected industry.(Polk,1991)

"In addition to quality standards, there is also physical form: What shape does a recyclable material have to be in use it in another manufacturing process? It is important to learn what industry expects and evaluates collection and processing program in terms of meeting the specifications being sold and reused."(Polk,1991) For example, a can itself that is not pressed is not a product because no aluminum smelters want it in that form. It will be required to be pressed and/or baled to a certain density in accordance with demand for end-use of the recycled materials. As will be pointed out in the following chapters, this densification process is applied to both aluminum and plastics.

"Another element of the product definition process involves looking at the industrial methods involved and the finished goods produced. Are the finished goods durable or disposable? Do the products resemble what they originally started out as or do they become a raw material input into an entirely different product?"(Polk,1991)

(ii)Identifying customers

Three "sub-markets" for recyclable materials are the following :

1. The processing market This is the market where most municipalities actually sell those materials which they do not process themselves. If municipalities own their own MRF, they are their own customer for this market. When municipalities use private processors, they must look at the processing market to determine how much it can handle, how the materials must be delivered, and what effect collection operations have on the quality of the materials.(BIO,1990/Polk,1991)

2. The manufacturing market Manufacturers are users of the processed recyclable materials. For the buyers in this market, the material must be in a form (a commodity) that can substitute for a virgin raw material (a competing commodity). This is also the market that most State economic development programs target.(Polk,1991)

3. The consumer market Final market is the area where the public can get involved.(Polk,1991) As mentioned earlier, continuous public education efforts will be effective for marketers of recyclable materials.

(iii)Evaluating supply and demand

In terms of post-consumer recycling, supply translates to the quantities of recyclable materials that recycling programs are recovering from MSW stream. For most municipalities, baseline data will consist of the tonnages disposed, multiplied by the percentage of materials available (determined through waste stream composition studies), and then factored by the number of residents within program boundaries and participation rate assumptions.

Once overall numbers are estimated, either through using national waste composition averages or data from each locality, these numbers must be interpreted in light of individual markets. Each recyclable material has its own characteristics that may help a locality in determining where to look for markets.(Polk,1991) Further discussion on this matter will be described in the following chapters (10 and 11).

When the quantities of material coming onto the market (supply) have been determined, the other side of the equation, buyer position (or demand) must be investigated. It will be important to examine materials individually to see what quantities are currently consumed by the processing market, the manufacturing sector, and if possible, the consumer sector.(Polk,1991)

PART FOUR
CHARACTERISTICS OF RESPECTIVE RECYCLING FOR ALUMINUM AND PLASTICS

In the preceding parts, the discussion focused on understanding all phases of recycling activities ranging from collection to marketing of recyclable materials as a whole. In this part, specific characteristics of recycling for post-consumer aluminum cans and plastic bottles, associated with historical and current features relevant to the markets of aluminum and plastics in both the U.S.A. and Japan, are discussed further. The characteristics of recycling for both materials come from not only their physical nature, but also economic and political environments.

Chapter 10. Characteristics of Aluminum Recycling

Section 1. Incentives to use of aluminum UBC

(i)Energy saving and resource conservation

Large rolls of flat aluminum sheet, known as "can sheet," are made from recycled aluminum used-beverage-can (UBC), and new aluminum cans are stamped out of this sheet. Besides UBC, scrap from post-industrial sources is also used to make can sheet. This sheet is considered to be high-quality aluminum. Using secondary raw materials such as UBC can net immense savings in energy costs required to make aluminum can sheet from virgin raw materials, on the order of a 95 percent reduction.(Alcoa,1987/ Misner,1989) Because of the high energy requirements for smelting alumina, energy accounts for about 20 percent of the cost of producing primary aluminum ingot through refining and smelting processes. Use of one ton of recycled aluminum avoids the use of 4 tons of bauxite and 700 kg of petroleum coke and pitch, along with avoiding the emission of 35 kg of toxic aluminum fluoride. Thus, the use of recycled aluminum represents an overall cost savings of about 40 percent. In addition, it is estimated that air pollution is reduced by 95 percent and water pollution by 97 percent.(Alcoa,1987)

(ii)Homogeneous and non-degradable nature

Relatively homogeneous recycled materials can be derived in aluminum recycling and also aluminum can be recycled indefinitely. The recycled raw materials of aluminum are indistinguishable from the virgin raw materials, and the benefits of aluminum recycling can be measured directly in terms both of reducing the demand for the raw materials used in the recycled product and of reducing short- and long-term disposal requirements. (EPA,1990/Misner,1989) As will be shown in Chapter 11, this situation is in marked contrast to recycled plastics which represent a mixed batch for recycling due to the variety of resins in the waste stream. But there are complications. Mass mandatory recycling of aluminum seems to be leading to decreased quality in the recyclable material. As many recyclables are commingled, including nearly indistinguishable steel/tin cans and aluminum cans, the possibility of contamination increases.(Misner,1989) Meanwhile, the comparison between the aluminum and steel/tin industry in the markets for beverage cans in both countries will be discussed in section 3.

Section 2. Recycling rates for aluminum UBC in both nations

(1)Recycling rates for aluminum UBC in the U.S.A.

From 1978 to 1987, the percent of aluminum cans collected increased from 27.4 percent (8 billion cans) to 50.5 percent (36.6 billion cans). In the U.S.A., almost every year since 1981, except 1986, over 50 percent of aluminum cans produced were recycled (refer to **Table 5**).(Alcoa,1987/ Misner,1989) According to a recent report of The Aluminum Association in the U.S.A., a national recycling rate for aluminum beverage cans is estimated at 60.8 percent in 1989. In some areas, the rate is even higher than the national average figure, however. For instance, California reports a 73 percent recycling rate. This is close to the 75 percent goal for the nation that the aluminum industry has set for 1995. In the Nineties, however, they want more than 75 percent reclaimed. The national rate reached the highest level of 63.6 percent in 1990 (see **Figure 2**). The total amount of aluminum cans collected in 1990 was approximately 55 billion cans. It is assumed that the recycling rate will be increasing in the future.

Table 5 - Aluminum UBC reclamation data in the U.S.A.(1978 - 1988)

Year	Pounds of Aluminum Collected (millions)	No. of Aluminum Cans Collected (billions)	Percent Aluminum Cans Collected
1978	340	8.0	27.4
1979	360	8.5	25.7
1980	609	14.8	37.3
1981	1,017	24.9	53.2
1982	1,124	28.3	55.5
1983	1,144	29.4	52.9
1984	1,226	31.9	52.8
1985	1,245	33.1	51.0
1986	1,233	33.3	49.0
1987	1,335	36.6	50.5
1988	1,499	42.5	54.8

Source : Misner, 1989/JACRA, 1989

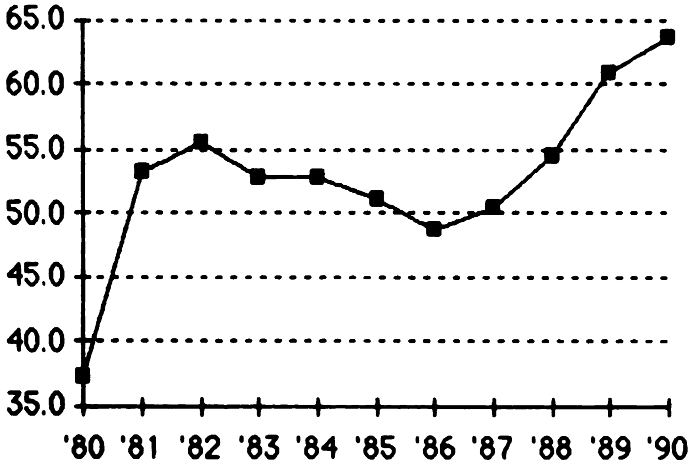

Figure 2 - Recovery rates for aluminum UBC in the U.S.A. (1980 - 1990)
Unit : %, Source : CMI, 1991

(ii)Recycling rates for aluminum UBC in Japan

The annual total amount of aluminum UBC generated in the fiscal year 1990 was approximately 8 billion cans or 148,000 tons (calculated based on 18.5 grams per can) (JACRA,1991), out of which 63,000 tons, or 42.6 percent, were collected during the same year. According to research conducted by Japan Aluminum Can Recycling Association in 1988, an estimated 70 percent of the total volume of aluminum UBC that were collected throughout this country during these years depends on several municipalities' efforts of implementing recycling activities. In Tokyo, however, the recycling rate for aluminum UBC is estimated at only a level of 10 percent in 1991. (NKS,1991c)

In the meantime, the Ministry of International Trade and Industry (MITI) has set an aluminum can recycling goal of 60 percent for the fiscal year of 1994, namely by the end of March in 1995. Steps for the implementation of the goal are as follows : 42.5 percent in 1989 (actual recycling rate), projected 44 percent in 1991, 48 percent in 1992, and finally 60 percent in 1994 (see **Figure 3**).(JACRA,1991)

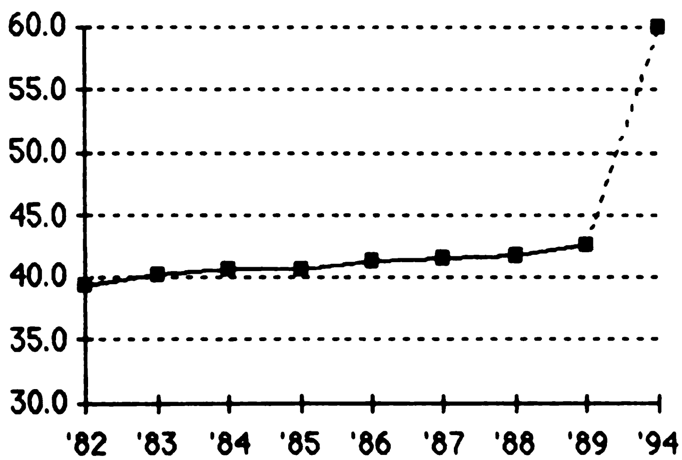

Figure 3 - Trend of recycling rates and future target for aluminum UBC in Japan (1982 - 1989 & 1994)
Unit : %, Source : JACRA,1991

Section 3. Aluminum versus steel cans in both countries

(1)The market of beverage cans in Japan

For the market for beverage cans in Japan, the steel and the aluminum industry are major competitors of each other.(NKS,1991c/JACRA,1991) They produce beverage cans used for beer, soda, tea (including Japanese, Chinese, and English) and other soft drinks. The total number of beverage cans produced annually in 1989 was 25 billion, out of which 17 billion cans were steel and the remaining 8 billion were aluminum.(JACRA,1991) The aluminum can industry has gradually been increasing its share of the market (see **Figure 4**). In Japan, the difficulty in manually separating aluminum cans from steel cans, which are nearly indistinguishable, seems to be one of the significant reasons for the actual recycling rates for aluminum UBC being maintained at a level much lower than those in the U.S.A.

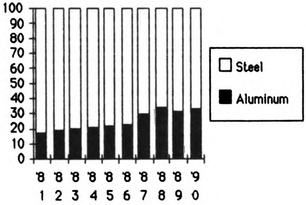

Figure 4 - Shares of aluminum and steel in the market of beverage cans in Japan (1981 - 1990)
Unit : %, Source : MPA,1991

(ii)Quantitative contrasts between the U.S.A. and Japan

Table 6 indicates quantitative contrasts between the U.S.A. and Japan with respect to the markets of aluminum and steel cans being used for bottled beverages such as beer and soft drinks. For the market scale of aluminum cans, the U.S.A. is more than eleven times as large as Japan. While in the U.S., the aluminum industry dominates the market of beverage cans (it holds 99.9 percent of the beer-can market), in Japan, the steel industry shares most part of the market as a whole. However, demand for aluminum beverage cans in Japan is so strong that, in the past year, some companies have imported finished cans, instead of raw materials, from the U.S.A.

Table 6 - Quantities of beverage cans distributed in the U.S.A. and Japan (1988)

U.S.A.	Aluminum cans	Steel cans	Share of Aluminum
Beer	36,200	30	99.9%
Soft Drinks	41,700	3,200	92.9%
Total	77,900	3,230	96.0%
Japan	Aluminum cans	Steel cans	Share of Aluminum
Beer	3,600	130	96.5%
Soft Drinks	3,200	14,200	18.0%
Total	6,800	14,330	32.3%

(Total number of aluminum cans sold in Japan in 1988 should be actually 7,400 million including 600 million of aluminum cans imported from overseas mainly the U.S. In that case, aluminum's share of the market is approximately 34 percent.)

Unit : million cans, Source : JACRA,1989

Section 4. Efforts by aluminum industries in both countries

(1)The aluminum industry's efforts in the U.S.A.

It is obvious that aluminum is the success story of packaging material recycling in the U.S.A. The primary reason for the success of aluminum-UBC recycling is the effort that the aluminum industry has put into setting up the nationwide network to successfully collect and reprocess aluminum UBC.(Alcoa,1987) Aluminum Company of America, Reynolds Metals Co., Anheuser-Busch, Inc. and Coors have successfully been leading a number of recycling programs for aluminum UBC throughout the country. All of these companies have their own subsidiary firms that deal with recycling of aluminum UBC in every locality.(JACRA,1991) In addition to environmental concerns, the aluminum industry has a strong monetary motive as described earlier. "In 1988, $900 million worth of aluminum UBC was collected, according to The Aluminum Association. This figure states that U.S. consumers are discarding about $800 million worth of cans which is going to the landfill, given the national recycling average of about 55 percent." (Misner,1989)

The first collection program for recycling aluminum started by an aluminum company was in 1967 in Florida, by Reynolds Aluminum. By 1972, hundreds of programs were in existence in the U.S., and the number is now over ten thousand. Estimates are that about 3 million Americans recycle aluminum cans on a regular basis. Non-profit groups have found aluminum recycling to be a profitable venture for their organizations. In 1987, it is estimated that individuals and charitable organizations in the U.S. received about $300 million for recycling aluminum beverage cans.(Alcoa,1987)

There are currently 31 primary aluminum producers and 111 secondary aluminum smelters in the U.S.A. The overall aluminum recycling rate in the country is about 25 percent, with about 25 percent of all recycled aluminum being cans.(Alcoa,1987) Containers and other packaging account for the largest source of post-consumer aluminum scrap. Two other significant categories are consumer durables (flatware, pots and pans, appliances, etc.) and transportation (autos, trucks, aircraft, railroad cars, boats, etc.). (Alcoa,1987/JACRA,1991)

As remarked in the beginning of Part Three, the aluminum industry in the U.S. expects to continue to diversify and possibly integrate vertically in its efforts to ensure a constant supply of secondary raw materials. Many manufacturers are looking to national service companies to form partnerships for collecting and consuming aluminum scrap. However, they will also continue stable relations with reliable suppliers, even charitable organizations on the long-term basis. Some producers will get into the business of collecting the raw materials themselves, which may involve setting up buy-back centers or commercial recycling companies. In some areas, these collection subsidiaries will even get into the business of waste hauling or disposal.

(ii)Historical and current recycling situation in Japan

In Japan, historically, as the first nationwide organization for aluminum recycling, the Japan Aluminum Can Recycling Association was established by efforts of major aluminum industries in 1973. The association has put their efforts into helping the public to become aware of social benefits related to aluminum recycling. At the next stage, Mitsubishi Metal Inc. set out with an innovative recycling business for aluminum UBC as the first private company in 1975. The subsidiary of this company, although the parent company's name was changed to Mitsubishi Materials Inc., has continued to do business as only one aluminum manufacturer that deals with the recycling of UBC for more than 15 years and succeeded in contributing to the increase of post-consumer aluminum can recycling rates across the country. Procurement of the recycling firm depends mainly on voluntary collection directed by schools, environmental groups, and so forth and partly on private carters and dealers. The company will pay one hundred yen per kilogram, or around $.27 per pound, for aluminum UBC, which is usually pressed to brick shape.(PIA,1991)

A total of 171 groups have already been set up across Japan since 1990, which includes 64 groups operated by mainly aluminum manufacturers, 44 organizations operated by especially retailers and distributors such as supermarkets, 28 managed by consumers union, and 28 by municipalities. In addition to these organizations, an institute has established in order to accomplish the MITI's goal, which is composed of the following seven groups: (1) aluminum producers, (2) distributors, (3) collecting agencies, (4) beverage makers, (5) community consumer unions, (6) local government agencies, and (7) volunteer groups.(NKS,1991c)

Section 5. Aluminum market's dynamics in the U.S.A.

The total of $1.7 billion in scrap value is likely to rise, as there are more aluminum cans being made every year. The soft-drink market in the U.S.A. is growing at about 5.5 percent annually. This growth rate exceeds that of the gross national product.(Misner,1989)

"There in no flinching in the aluminum recycling markets over a possible glut due to an increase in supply of cans from recycling programs of both mandatory and voluntary. The aluminum market's dynamics are different than those for newspaper and other recyclables. No new end-markets need to be created to absorb increased aluminum UBC recycling in the Nineties. As a result, UBC and other aluminum scrap should keep an inherent value. Price fluctuations are to be expected in the sensitive demand and supply atmosphere of aluminum, but nothing as drastic as today's old newspaper problem."(Misner,1989)

Capacity problems are not a concern, even if the new can market's growth cannot absorb all of the aluminum UBC. High-quality sheet made with UBC can be used for a number of different, lower-grade applications if necessary. Furthermore, Alcoa, the leading can producer with a 29.6 percent share of can-making capacity, says it has yet to plateau on the production side. Large economies of scale enable many producers to increase capacity without much loss. And there is room for growth elsewhere. The aluminum industry is looking to edge into the food-can market, which is presently dominated by the steel can. Demand for aluminum can sheet has increased over past two years, as aluminum's market share in food doubled. Steel-can makers are finding aluminum giving tough competition in the medium-sized can range, such as with juice cans. Over the next ten years the aluminum industry looks toward capturing a third of the food can market. Even aluminum's strongest proponents, however, concede that larger, 32-ounce cans require steel for strength. In terms of the scale of these two markets, the number of beverage cans outdistances the number of food cans by about 60 billion.(Misner,1989)

"In the secondary aluminum market, most scrap dealers expect a period of soft prices at the beginning of the Nineties. These sources work with aluminum cast, extrusions, and other varieties of scrap aluminum. However, at a recent aluminum scrap dealer meeting sponsored by the Institute of Scrap Recycling Industries in Chicago, most dealers agreed the market looks good for secondary aluminum, as demand continues to chase a relatively tight supply. Some believe the scrap-to-prime ratio will narrow in the future, meaning the percentage of scrap used in making new aluminum will grow. In an atmosphere of caution, scrappers look toward to a favorable but very competitive market in the Nineties."(Misner,1989)

Looking at basic supply and demand characteristics of the secondary aluminum market, especially can sheet, the Nineties appear to be a time of strong market activity. Demand for the aluminum can seems to be growing on a number of fronts, and supply has the potential to grow equally as strong without experiencing major complications such as shortages.(Misner,1989)

Chapter 11. Characteristics of Plastic Recycling

A number of characteristics concerning plastics may affect all phases of the plastic recycling and tend to differentiate the technical, economic, and political considerations for post-consumer plastic recycling from those for recycling of other solid waste constituents. The following paragraphs will indicate those characteristics that significantly influence performance of post-consumer plastic recycling.

Section 1. Mixed nature of post-consumer plastics

(i)Variety of plastic wastes

"Plastics encompasses an extremely broad range of materials. Plastic products in MSW are a very heterogeneous collection of materials. They include not only items made from a single resin, but an increasing number of items that include a blend of resins. The blending of resins in individual items may involve the simple physical joining of two or more resins, for example, PET drink containers with HDPE base cups, or the chemical bonding of different resins in a single plastic film. Further, the nature of additives incorporated to yield specific plastic qualities is diverse."(EPA,1990)

Mixed-resin products and the presence of a variety of additives may significantly affect recycling options. For example, many mixed-resin products are amenable only to mixed-plastic processing technologies, while the presence of some additives may complicate the use of some or all recycling technologies for some plastic items.(EPA,1990) The mixed nature of most post-consumer plastics, which is derived from the variety of resins in the waste stream, has significant implications in estimates of the long-term benefits of plastic recycling. This contrasts with the relatively homogeneous recycled products made of aluminum scrap.

(ii)Difficulty of sorting plastic resins

Plastics segregated from MSW include a variety of resins. It is not always necessary to separate plastics by resin type to allow their recycling, but separation by resin can allow the production of the highest-quality recycled products.

It is technically difficult to separate relatively pure resins from mixed plastics collected for recycling. Commercially demonstrated separation technologies are almost exclusively limited to processes that separate PET and HDPE. A number of promising technologies to effect separation of mixed plastics are under active development, including infrared analysis, laser scanning, gravity separation, and incorporation of chemical markets into different resins. Successful development and implementation of one or more of these technologies may allow reliable separation of mixed plastics into homogeneous resins.(EPA,1990)

(iii)Quality of recycled resins

All processing methods for recycled-plastic resins cause some physical degradation and chemical change of the resins.(EPA,1990) Therefore, recycled resins may not be suitable to replace virgin resins in many applications with exacting quality specifications, particularly in food-contact packaging applications. However, with good separation of collected plastics into homogeneous resins of cleanliness, they may be used to make a broad range of products that would otherwise be made from virgin resins, or may be incorporated into mixed raw materials with virgin resins. The plastic products using only homogeneous reclaimed resins may be able to compete with those using virgin resins in terms of quality. With current processing technologies for mixed plastics, however, recovered resins are incorporated into products with less demanding physical characteristics, for which market competition comes not from virgin plastics but from other commodities like lumber or cement.(EPA,1990)

This situation is in marked contrast to recycling scenarios for aluminum and glass from MSW. For these MSW constituents, the recycled raw material is indistinguishable from the virgin raw material, and the benefits of recycling can be measured directly in terms both of reducing the demand for the raw materials used in the recycled product and of reducing short- and long-term disposal requirements.(EPA,1990)

(iv)Long-term impacts of mixed-plastic recycling

"Whereas processes using homogeneous resins displace consumption (and disposal) of virgin plastics, those using mixed plastics do not displace the use, nor ultimately the disposal, of virgin plastics. Instead, they compete with and displace consumption, use, and disposal of other commodities like lumber or cement. Ultimately, the mixed-plastic recycled products must themselves be disposed of. Therefore, benefits of mixed-plastic recycling may be most appropriately measured in terms of the long-term deferment, rather than the elimination, of plastics disposal requirements."(EPA,1990)

Technical and political considerations, which frame the potential role and impact of mixed plastic recycling, are as follows :

* To the extent that products made from mixed plastics do not compete with those made from virgin plastics, mixed plastics recycling does not reduce the demand for or the consumption of virgin plastics.
* It is difficult to exactly determine the recyclability of recycled products using mixed resins. However, they may not be acceptable as a stable raw material for repeated recycling, since processing technologies for mixed plastics generally cause some degradation of physical characteristics of their constituent resins.

  If the products are not recyclable, mixed-plastic recycling will not reduce the ultimate requirement for plastic disposal. When the products are disposed of, all of their plastic contents enter the waste stream.
* Mixed-plastic recycling reduces total waste disposal requirements. Even if it has no long-term impact on plastic disposal requirements, it does reduce total long-term waste disposal. "For example, if one cubic yard of recycled post-consumer plastic displaces consumption of one cubic yard of lumber in a product application (e.g., for fencing), the total disposal requirement at the end of the plastic lifecycle is one cubic yard. However, if plastic recycling is not implemented, total disposal requirements are two cubic yards (one cubic yard of post-consumer plastic plus one cubic yard of lumber from the fencing application). (A related topic potentially deserving further investigation is the relative environmental impact of mixed recycled plastic disposal compared to disposal of displaced nonplastic products; for example, the potential environmental impacts of plastic "lumber" disposal appear to be qualitatively different from those that may be associated with disposal of pressure-treated wood.)"(EPA,1990)

For these reasons, measuring the benefits of mixed-plastic recycling is complex. If products recycled from mixed-plastics cannot themselves be recycled, then the benefits of mixed-plastic recycling must be measured in terms of deferring, rather than eliminating, long-term plastic disposal requirements. However, this delay in itself may be a substantial benefits. For example, it puts recycled plastics to productive use for a number of years, during which recycling technologies may be expected to improve, and so to allow the further recycling of the initial recycled product. And even if mixed-plastic products cannot ultimately themselves be recycled, and so have no long-term impact on plastic disposal, their use does reduce total disposal requirements for all wastes.(EPA,1990)

Section 2. Recycling rates for each plastic resin

Current recycling rate for post-consumer plastic wastes is estimated at approximately 1 percent. As shown in **Table 7**, most plastic-recycling efforts to date have focused on PET soft-drink bottles and to a lesser extent on HDPE milk jugs. In total, only about 1 percent of the post-consumer plastic wastes is recycled.(EPA,1990) The total U.S. market for plastics was estimated, at almost 57 billion pounds, or 28.5 million tons, in 1988. Of this, 13.8 billion pounds were used for packaging applications, and accounted for about 60 percent of plastics in MSW stream.(Schell,1989)

Table 7 – Data on plastic packaging in the U.S.A. (1988)

Resin	Quantity produced	Quantity recycled
LDPE	4,310	
HDPE	4,260	90 (2.1%)
PE	1,420	
PS	1,545	
PET	990	150 (15.2%)
PVC	760	
Other	520	
Total	13,805	240 (1.7%)

Unit : millions of pounds, Source : Schell,1989

(1)PET

PET is obviously the primary target of plastic recycling. The 15 percent recycling rate for PET, as shown in **Table 7**, is actually higher than the 11 percent for all MSW.(Schell,1989)

Wellman Inc., which currently dominates the market for recycled PET, processed 100 million pounds of PET in 1988 and currently has the capacity to process an additional 70 million pounds. The company can use up to 450 million pounds annually, or 45 percent of the PET currently used in packaging.(Schell,1989)

"The use of PET for packaging is predicted to grow from currently just over 1 billion pounds to about 1.8 billion pounds by 1993. The majority of this growth in volume is expected from the beverage industry, growing at just under 10 percent a year. In the past decade, recycling of PET beverage containers has grown rapidly from approximately 8 million pounds in 1979 to well over 200 million pounds today."(Barham,1991)

(ii)HDPE

"HDPE milk bottles are currently being recycled in a few locations, including N.E.W. Plastics in Wisconsin, Eaglebrook Plastics in the Chicago area, and Plastics Recycling in Iowa. Recycling of HDPE drums and of HDPE motor-oil bottles is being explored. For the most part, problems with expanding HDPE recycling are economic rather than technical. Virgin PET sells at 53-60 cents per lb. Blowmoulding grades of HDPE sell for only 30 cents per pound, resulting in considerably less margin for recycled polymer to be competitive. In addition, HDPE does not have the built-in source of supply provided for PET by bottle deposit legislation. Only a few communities have any type of collection program and those in existence are usually drop-off centers in operation only a few days per month. Thus collection is much more of a problem for HDPE than for PET."(Selke,1988)

Blow-molded HDPE bottles accounted for 2.3 billion pounds, or almost 55 percent, of the HDPE used in packaging. HDPE base cups for PET bottles accounted for an additional 130 million pounds. Most of the current recycling of HDPE centers around collection and processing of HDPE milk jugs and base cups on PET soda bottles.(Schell,1989)

As the recycling industry develops, collection programs are expected to add colored HDPE containers, such as detergent bottles, as well. Most of the companies that are building new PET facilities are also including capacity for processing HDPE in order to take advantage of growth opportunities in this market. HDPE capacity additions should be similar in magnitude to the 110 million pounds being added for PET.(Schell,1989)

An additional source of new capacity will probably come from companies currently using reground virgin HDPE. According to the Plastics Recycling Foundation, these firms could add the equipment to shred and clean scrap HDPE for $250,000 to $500,000, and thus be able to mix virgin and recycled resin.(Schell,1989)

(iii)Joint ventures for PET and HDPE

In response to public pressure to increase post-consumer plastic recycling, joint ventures have been formed between the larger waste hauling companies and plastic firms (see **Table 8**). These joint ventures serve two purposes. One of these is to combine the ability to collect a clean and homogeneous post-consumer plastic, and the capability to process it. However, the more important purpose behind the joint ventures is the desire to secure a reliable scrap-plastic-feed source in order to reduce the risk associated with establishing the infrastructure for plastic recycling. The joint ventures have been concentrating on PET and HDPE, because only PET and HDPE have currently been recycled in significant quantities. (Schell,1989)

Table 8 - Joint ventures between the waste hauling and plastic industries

Waste hauling firm	Plastic firm	Resins recycled
Waste Management, Inc. Oakbrook, Il	Dupont Wilmington, DE	PET, HDPE
BFI Houston, TX	Wellman, Inc. Shrewsbury, NJ	PET, HDPE
Domtar Toronto, ONT	Dow Chemical Midland, MI	PET, HDPE

Source : Schell,1989

(iv)LDPE

LDPE is technically just as recyclable as HDPE. However, since its major use in packaging is in film applications such as supermarket bags and stretch wrap, rather than in rigid containers like HDPE, an effective means of collection has not yet been developed. One approach to collect plastic bags is to hand pick them, along with other materials, from refuse. A number of organizations are pursuing research on separating this resin from a mixed-plastic stream.(Schell,1989)

Section 3. Features associated with collection alternatives

Although technologies exist to segregate metals and glass from MSW after collection, currently available technologies are much less effective at capturing plastics after collection. There are some instances showing this situation. In the early 1970s and US Bureau of Mines was very active in research on separation of plastics from MSW and further separation by resin type. Typical separation methods include sink-float methods for separation by density, similar systems using surfactants or swelling agents when densities are nearly the same, electrostatic separation processes, hydraulic separators, and air classifiers. As a result of this research, it was found to be very difficult and expensive to achieve a product suitable for secondary recycling.(Selke,1988) In contrast, it is considerably easier to remove the potentially recyclable plastics before they are mixed in with other MSW. This will result in much less contamination to deal with. For these reasons, nearly all discussions of plastic-collection alternatives have focused on possibilities of capturing plastic recyclables before they enter the MSW stream.(EPA,1990/Selke,1988) The following discussion also reflects this focus.

(1)Problems relevant to curbside collection

Curbside collection that accepts plastics may provide the vehicle for capturing the greatest variety and amount of plastic waste. However, this strategy is not universally applicable, but imposes relatively high costs for collection. In addition, this may result in collection of a variety of mixed plastics, if many are collected, that may not be amenable to the processing method that produces the highest-quality products,(EPA,1990/Selke,1988) because mixed plastics are difficult to sort by resin type with currently available technologies.(EPA,1990)

In most practicable implementation scenarios, curbside programs collect a mixture of plastic wastes. In many current programs, mixed plastics are also commingled with recyclable nonplastics. Therefore, implementation of curbside programs either demands that efficient plastic separation strategies be implemented to allow the capture of homogeneous resin streams, or implies that only mixed-plastic technologies will be available as processing options for the collected mixed plastics.(EPA,1990)

(ii)Costs of adding plastics to curbside programs

Few curbside programs currently accept plastics as one of the targeted recyclable materials, although the number of the programs that collect plastics is growing steadily. For this reason, either historical or current, few cost data on inclusion of plastics in curbside programs are available. (EPA,1990/BIO,1990/Schell,1989) However, from an economic viewpoint, for success of plastic recycling, it is important to clarify the incremental costs and revenues associated with adding plastics to curbside collection programs.

For a number of communities in Rhode Island, estimates of the increases in hauling time and cost associated with adding plastics to established curbside collection programs are presented (see **Table 9**). The average increase in both the time and cost among these communities is 67 percent. On the other hand, CPRR calculated the cost of adding plastics to a curbside collection in 1988. The result is that, under a plausible base case recycling scenario, the inclusion of plastics would increase net economic benefit of the collection program by approximately 5 percent.(EPA,1990)

Table 9

Cost impacts of adding plastic to Rhode Island curbside collection programs

City/Town	Annual round trip time per truck (hrs.)				Annual cost per truck ($)			
	No plastic	With pl.	Increase	% incr.	No plastic	With pl.	Increase	%incr.
Cranston	291	485	194	67	8,046	13,410	5,364	67
E. Greenwich	229	343	114	50	6,919	10,378	3,459	50
E. Providence	416	624	208	50	11,132	16,698	5,566	50
Johnston	153	267	114	75	4,114	7,199	3,085	75
Newport	607	970	363	60	16,617	26,587	9,970	60
N. Kingston	302	603	301	100	8,508	17,016	8,508	100
Warwick	286	515	229	80	7,876	14,178	6,302	80
W. Warwick	302	503	201	67	7,305	12,175	4,870	67
Woonsocket	425	667	242	57	10,498	16,496	5,998	57
Mean	335	553	218	67	9,002	14,904	5,902	67

Source : EPA,1990

(iii)Combinations of collection alternatives

"A few States are considering extension of deposit laws to a broader spectrum of plastic products (i.e., not only beverage containers), but nationally little momentum is apparent toward such policies. To expand the range of items collected under container deposit legislation would obviously increase the proportion of MSW plastics collected under deposit programs, but this option has drawbacks. First, it will probably tend to reduce the volume of resins available to secondary processors requiring homogeneous inputs (unless effective separation technologies are implemented). Second, it may interfere with the success of curbside collection programs, primarily because of its negative impact on costs and benefits of curbside collection."(EPA,1990)

"Combinations of deposit legislation and other collection alternatives may prove to be effective recycling policy options. For example, deposit legislation expanded to selected additional containers (of known, standardized resin content) might effectively capture a large proportion of MSW plastics amenable to homogeneous resin processing technologies. Although curbside collection would then capture only the remaining mixed plastics, there would be no requirement to sort these wastes, and they could be fed directly into mixed-plastic processing technologies. The net result might be the optimization of both the total diversion of plastics from disposal and the yield of resins amenable to homogeneous-resin processing technologies."(EPA,1990)

(iv)Factors of incremental costs

The most significant cost impact of adding plastics to an established collection program is related to the fact that plastics have a very low density compared to other commonly collected materials.(EPA,1990) Increased program costs are also associated with processing plastics and transporting them to a buyer. Baling plastics may require 10 to 12 times more baler strokes than baling a similar volume of newspaper. And when bales are transported, a 40 cubic yard trailer can hold only about $135 worth of PET plastics, compared to $240 worth of baled newspapers, based on 1988 prices. When these and other costs are totaled, the net cost of adding plastics to an established collection system is approximately 8 cents per pound recovered, or $160 per ton. Against these costs must be balanced the sales revenues generated by the recycled plastics, and the avoided cost of tipping fees.(EPA,1990)

(v)Further recycling of recycled products

Most of the current recycled products made from mixed resins are not targeted for consumer applications, but for commercial or industrial use. In these applications, a collection infrastructure has not been established, and it is unlikely that the recycled products will be captured for further recycling.(EPA,1990)

Section 4. Distinctions among separation options

For plastic recycling to be feasible, separation options involve two major considerations :

(1) Separation of plastics from non-plastic contaminants, or from other components of the waste stream. Non-plastic contaminants typically include dirt, food residues, labels, etc.(EPA,1990/Selke,1988)

(2) Separation of various types of plastic from each other. The amount of separation of types of plastic from each other will be strongly dependent on both the nature of the plastic stream being collected and the end use for which the recycled material is intended.(Selke,1988)

The following discussion is focused on the separation of recycled plastics by resin type.

(i)Contrast between homogeneous and mixed plastics

"One of the difficulties of recycling plastics is that not all plastics are alike, and further, they tend to be incompatible with one another. Typically, components in blends of two or more types of plastics are mutually insoluble and therefore exist in discrete phases. Morphology of structure will depend not only on the amounts and types of the components but on processing method, especially the amount and type of mixing. Generally, small regions of one phase in a continuous matrix of the other phase produce the most favorable properties in two-phase systems. To achieve this, mixing at high shear is generally required. Even then, the resulting materials frequently tend to be brittle and not very strong."(Selke,1988) Products yielded by technologies using inputs of mixed, potentially contaminated plastics are typically limited to items with fairly large cross-sections which compete not with virgin resin products, but with commodities like lumber and concrete structures. Markets exist for the products of these technologies, but continued growth of the mixed-resin recycling industry may depend on the identification of additional markets, technological developments to increase product quality, and reduction of costs to increase cost-competitiveness in identified markets.(EPA,1990) Such objects can often incorporate substantial amounts of nonplastic materials as well, eliminating the need for stringent removal standards for label fragments, etc. This is obviously the only type of recycling suitable for multilayer coextruded structures, which by their very nature cannot be separated into individual resin components. Recycling of mixed plastics has not been practiced commercially in the U.S.A. until very recently and it is too soon to judge its success. It has met with at least some success in Europe and Japan.(Selke,1988) Unless the products of this recycling are recycled themselves, this process will not ultimately reduce requirements for plastics disposal.(EPA,1990)

On the other hand, much better properties can be obtained from recycled plastics that are homogeneous in chemical type, than from mixed resin. The recycling technologies employ inputs of relatively homogeneous recycled resins to yield products that compete with those made from virgin plastic resins. Although there are no foreseeable limitations on markets for products using these technologies, their deployment is currently constrained by limited supply of clean, homogeneous recycled resins. They offer the greatest potentiality to reduce long-term requirements for plastic disposal.(EPA,1990)

(ii)Separation of collected plastics into homogeneous resins

Recycled plastics may be processed either as homogeneous resins or as mixtures of resins. Mixed resin processes currently yield products that only rarely displace virgin resins. The following discussion presents a number of alternatives currently or potentially available to facilitate the separation of collected recycled plastics into homogeneous resin types. The greatest long-term diversion of plastics from the waste stream promises to be realized if separation techniques are available that make homogeneous resins available to recycled plastics processors. The following discussion reflects both widespread interest and active efforts to refine such techniques.(EPA,1990)

The primary alternatives available to allow separation of homogeneous resins from collected recyclable plastics include :

1. Separation after compaction or shredding
2. Container labeling and automated separation
3. Manual segregation by resin at the point of collection
4. Collection focused on specific resin or container types
5. Standardization of resin contents of recyclable products

1. Separation after compaction or shredding

"Separation of mixed resins after shredding into homogeneous resins is technically difficult. For well-characterized mixtures of two known resins, such as PET and HDPE recovered from beverage bottles, density separation may be possible. This technology is currently employed to segregate shredded PET/HDPE bottles into their constituent resins for recycling. But the wide variety of resins present in commingled-plastic wastes, and the very similar densities of many of these resins, effectively preclude the use of density separation techniques for assorted-mixed plastics. For example, PET and PVC are of similar density and thus difficult to separate. No other technologies currently available or under development appear capable of achieving reliable separation for mixed plastics after shredding. Separation of crushed containers may be feasible, however."(EPA,1990)

2. Container labeling and automated separation

The Society of the Plastics Industry (SPI) has instituted a voluntary labeling system for recyclable-plastic containers. The molded label contains a code specifying the primary resin incorporated into the product. These codes have been voluntarily adopted by much of the plastic processing industry and are currently beginning to appear on containers distributed in consumer markets. Fifteen States have made use of the SPI codes mandatory on rigid plastic containers distributed in the State. Several other States are considering such actions.(EPA,1990)

There is significant industry interest in these technologies, and a number of implementation alternatives are under active development. These technologies face foreseeable barriers, however, primarily economic and institutional.(EPA,1990)

"Economic barriers include : 1) the potential cost of such systems; 2) costs imposed on municipalities or other recycling agencies to transport uncrushed (with some technologies), unshredded containers to the sorting facility. An institutional barrier is also associated with these economic considerations, in that the expense of the systems may make them feasible only if implemented in regional (e.g., county-wide) processing centers, which in turn may require a coordinated infrastructure among governments in a region."(EPA, 1990)

This option is most compatible with curbside collection programs and drop-off recycling centers, because these programs promise to provide large volumes of mixed-plastic wastes. Automated separation is also compatible with container deposit legislation, if the legislation is extended to a broad range of recyclable containers.(EPA, 1990)

Development of this alternative may also be determined, to some extent, by growth of markets for the recycled products of homogeneous resin. If these markets continue to develop, processors may demand greater quantities of homogeneous recycled resins. Such demand may drive the development of automated plastic separation.(EPA, 1990)

3. Segregation by resin at the point of collection

If a uniform labeling system is conventionalized, plastics may be segregated manually by resin type as they are collected for recycling. While this separation scheme is technologically simple, it is labor intensive. The inconvenience to consumers of scanning and separating products by resins would result in low public participation. If collection agencies also must sort the wastes, significant labor costs will be imposed. Costs will also be imposed at the point of collection for the storage of recyclables, and potentially for the transport of sorted recyclables to processing facilities (although shredding or compaction at the point of collection may allow this expense to be avoided).(EPA, 1990)

Nevertheless, a number of communities perform manual sorting of recyclables. Typically, their collection and separation efforts have focused on only one or a few classes of plastic articles, including HDPE milk jugs and PET/HDPE beverage containers. Some of these communities have worked in conjunction with human service agencies to employ handicapped citizens for sorting tasks. These citizens provide a low-cost work force for the recycling program, and benefits are also measured by the provision of meaningful work for this segment of the population.(EPA,1990)

4. Collection focused on specific resins or container types

A number of municipal recycling programs focus on a limited subset of all recyclable plastic containers. For example, some communities (e.g., Naperville, Illinois) have focused on HDPE milk jugs in their recycling efforts, while most container deposit legislation affects primarily PET/HDPE beverage containers. Such focused recycling efforts by definition can yield an easily characterized, homogeneous recyclables, and offer the advantages of consumer convenience and relatively low cost to recycling agencies. However, they would result in the collection of only a small fraction of potential recyclable plastics. Nevertheless, based on the purchasing activity of recycled plastic processors, this strategy has proven very effective in capturing the homogeneous-resin streams required for plastic recycling technologies dependent on homogeneous-resin inputs. (EPA,1990)

Use of this strategy may continue to expand with any expansion of bottle deposit legislation, or use of reverse-vending machines. If the scope of deposit legislation is expanded, however, such legislation may result in collecting more mixed-plastic wastes, instead of homogeneous resins.

5. Standardization of resin contents of recyclable products

One of the most intractable problems in mixed-plastic recycling is the great variety of resins in MSW. It may be desirable to apply uniform standards for resin content across at least some classes of plastic containers to facilitate their separation into a homogeneous stream of recyclable plastic. This option is not really a separation strategy in itself, but facilitates the coding and separation of a potentially wide selection of plastic products. This strategy has been used in West Germany and the Netherlands, where the Coca Cola company has worked with a bottle producer and government agencies to develop a single-resin beverage container to support recycling programs.(EPA,1990)

"Barriers to growth are significant for this option. It affects the business decisions of potentially thousands of producers and marketers. Resin and additive contents are often dictated by specific product needs (e.g., for vapor impermeability, transparency or translucence, chemical resistance to specific compounds), and so may be impractical for government authorities to review or assess. Nonetheless, for a limited range of items with common characteristics (e.g., beverage containers, milk jugs, detergent bottles), standardization may spread through voluntary industry agreements (based on the perceived public public relations value of marketing in recyclable containers), which might be encouraged by government involvement." (EPA,1990)

(iii)Outlook for the separation situation

"No technologies are currently widely employed to effect the separation of resins from mixed-plastic wastes. The most effective means currently employed to yield homogeneous recycled resin streams is to focus collection efforts on one or a few products containing a correspondingly small number of resins. Two additional strategies may facilitate the collection of homogeneous resin streams: 1) development of standard container labeling and automated sorting equipment, and 2) voluntary use of standardized resin contents in some classes of plastic products. Significant industry efforts are underway to develop automated sorting technologies. Within a few years these may allow mixed recycled plastics to be sorted efficiently and cost effectively."(EPA,1990)

Section 5. Densification processes

As mentioned earlier, plastics have a high ratio of volume/weight, or a low density for the most part, compared with other recyclable constituents of MSW. The density of collected plastics is less than 30 pounds per cubic yard for uncrushed containers (40-50 pounds per cubic yard for hand-crushed PET containers), compared to 50-75 pounds per cubic yard for uncrushed aluminum cans (250 pounds per cubic yard for crushed aluminum cans), 145 pounds for mixed-recycled metals, 500 pounds for newspaper, and 600-700 pounds for whole glass bottles.(EPA,1990) Densification at an early stage, by either grinding, or baling, or shredding, or crushing at the point of collection, is often essential to the overall economics of plastic recycling. (EPA,1990/Selke,1988) However, densification can reduce the practicality of separation into homogeneous resins.(EPA,1990)

Section 6. Processing technologies for collected plastics

Depending on the nature and homogeneity of resins available from collected post-consumer plastics, a number of processes are available to produce recycled-plastic products. They are generally grouped into three categories.

(i) Primary processes

Primary processes are defined as industrial recycling of manufacturing and processing scrap. Typically, such scrap is blended with virgin resins and reintroduced into plastics production processes.(EPA,1990) However, primary plastic recycling is not addressed in this thesis.

(ii) Secondary processes

Secondary processes include a variety of technologies distinguished by the nature of required inputs and by the characteristics of their products. They are commonly differentiated by the nature of resins input to the process :

1) Secondary Processes/Homogeneous Resins - yield products that compete with the products of virgin resins.
2) Secondary Processes/Mixed Resins - yield massive or thick-walled products that may replace lumber, concrete, or ceramics.

"Secondary processes encompass a continuum of processing alternatives. One end of this continuum is defined by processes that consume clean, homogeneous resins that can be used to manufacture products interchangeable with those produced from virgin plastic resins. At the other end of this continuum are processes that consume mixed recycled plastics in the manufacture of products that do not replace or compete with virgin plastic products, but replace structural materials such as wood and concrete in product applications."(EPA,1990)

1. Secondary processing technologies/homogeneous resin inputs

These processing technologies are generally the same as or similar to those used to process virgin plastic resins, and demand inputs of high resin quality and homogeneity.(EPA,1990)

"Secondary recycling processes for homogeneous resins typically heat recycled plastics (or a blend of recycled and virgin resins) into their melt range and use any of a number of production processes (e.g., injection molding, extrusion) to yield a final product. These processing technologies are the same as or very similar to those employed with virgin resins; as such, they are "mature," cost-effective, and well characterized. They are capable of processing inputs of recycled resins into high-value products and are currently supply-limited. To date, such processes have been employed primarily with homogeneous resin streams from recycled PET/HDPE beverage containers and HDPE milk jugs."(EPA,1990)

Commercially successful system producing homogeneous recycled plastic technically set out with only one type of resin or one type of container. Recycled PET and recycled HDPE from the base cups are produced by several commercial or pilot-plant recycling operations, including St. Jude Polymers, Star Plastics, Nelmor, Envipco, and CPRR at Rutgers University.(Selke,1988)

2. Secondary processing technologies/mixed-resin inputs

Secondary processing technologies using mixed resin inputs yield products with relatively non-demanding physical and chemical characteristics. Typically, mixed resins are heated (generally by pressure and friction) above the melt points of the dominant resins in the blend and extruded or molded into desired product shapes. Plastics that do not melt in the blend (and other contaminants) are encapsulated and serve as filler in the final product; other materials (fillers, colorants, stabilizers, flame retardants, etc.) may be added during the blending process to yield desired product qualities.(EPA,1990)

Some of the products made from mixed-resin secondary processes include : plastic "lumber" (suitable for boat docks, fence posts, animal pens, landscaping applications, etc.), car stops, railroad ties, pallets, gratings, man-hole covers, and cable reels.(EPA,1990)

Mixed-resin secondary processes are currently available and have been developed by a number of firms in the U.S. European countries (especially Germany) and Japan have been leaders in developing and implementing these technologies. They continue to face a number of technical and economic barriers, however. Technically, these technologies face the challenge of producing higher-quality, higher-value products from mixed plastics inputs. Their current range of products competes with low-value commodities in relatively limited markets. Both market diversity and product value must increase in order to absorb a large proportion of recyclable mixed plastics. Economically, the costs of these processing technologies must be reduced to allow their products to compete effectively in established markets, because the long lifespans and maintenance-free qualities of their products may not be sufficient to overcome consumer resistance to high initial purchase prices. With currently available technologies, most mixed recycled plastics are processed into generally lower-value products that compete in markets with such materials as lumber and concrete.(EPA,1990)

(iii) Tertiary processes

Tertiary processes involve the chemical change of recycled plastics into chemical constituents that serve as fuels or chemical feedstocks. Tertiary processes may use either mixed or homogeneous plastics as raw materials to yield monomers or oligomers used as fuel (mixed-plastic inputs) or as chemical feedstocks (pure-resin inputs).(EPA,1990)

Processing technologies are defined primarily by the purity of their required input streams and the quality of their products. As has been noted, homogeneous inputs are required for technologies that can use recycled plastics in blends with virgin resins or that can produce products competitive with products manufactured from virgin resins. As input quality falls, output products tend not to displace consumption of virgin plastics, but to compete in markets with lower-value commodities such as lumber and concrete. The products of tertiary recycling processes (monomers and oligomers resulting from the nearly complete breakdown of plastic resins) do not compete with plastics strictly defined, but with the raw materials to plastic production processes.(EPA,1990)

Tertiary processes recover basic chemicals and fuels from waste plastics. "By far the most common tertiary process is pyrolysis, in which wastes are heated in the absence of oxygen, driving off volatile components of the inputs (plastic monomers and oligomers and other products) and leaving a char consisting mainly of carbon and ash. The mix of products and their potential uses are determined both by the nature of the input stream and by pyrolysis conditions; they can include combustible gases useful as chemical feedstocks and gases and liquids that can be used as fuels. Recycling processes that are often termed "tertiary" employ a wide variety of inputs, ranging from mixed plastics and nonplastics to very pure resins, to yield products consisting of hydrocarbon fuels and possible chemical feedstocks. Only the latter outputs result in effective plastics recycling, but their production demands the use of nearly pure resins, which are in limited supply, as inputs to the tertiary process."(EPA,1990)

"Tertiary processes can be employed with a wide variety of inputs, including mixed organic wastes (e.g., all combustible fractions of MSW), mixed plastics wastes, or homogeneous plastic resin streams. Control over outputs is greatest when inputs are well characterized and consist of only one or a few known constituents. Only if these conditions are met do tertiary processes yield products of sufficient quality and purity to be used as chemical feedstocks; as input quality declines, tertiary products are generally useful only as fuels (and the distinction between tertiary recycling and simple incineration tends to be obliterated). The primary advantage of tertiary processes is their ability to be used with mixed plastics or with mixed-plastic/nonplastic wastes. If used with such wastes, however, tertiary processes tend to become a disposal rather than a recycling alternative. Because tertiary processing technologies can also be employed with homogeneous plastic waste streams to yield high-value chemical products, they may also compete with homogeneous-resin secondary processing technologies as an option to recycle sorted and well-categorized resins separated from MSW."(EPA,1990)

Section 7. Marketing of recycled plastic products

The final step in a plastic recycling system is end-use of the recycled material. Suitable uses obviously depend on the quality and properties of the material.(Selke,1988) In addition, the presence of adequate markets for recycled plastic products will be a critical determinant of the potential for recycling to divert a significant proportion of plastics from MSW disposal. Substantial markets exist for the products of secondary processes employing homogeneous resins and those of some tertiary processes, and that market opportunities should not limit the growth of these technologies in the foreseeable future.(EPA,1990)

The following paragraphs summarize published estimates of current and potential markets for recycled-plastic products. Published quantitative estimates have focused on markets for recycled PET and HDPE products, because these resins have been those most widely targeted under currently implemented collection strategies, and on the products of secondary processes using mixed resins.(EPA,1990)

(i)Markets for unprocessed recycled plastics

In addition to the U.S. and foreign markets for recycled-plastic products, foreign markets may exist for unprocessed or partially processed recycled plastics. "In a Massachusetts study, less developed countries were singled out as a large potential market for recycled resins, and some recycling programs have specifically targeted foreign processors to accept recycled resins. No quantitative estimates of these markets exist, however, some evidence suggests that these markets may be very volatile, and so may not be reliable as a market for large volumes of recycled resins."(EPA,1990)

(ii)Markets for secondary processes using homogeneous resins

Substantial markets appear to exist for the products of secondary recycling processes employing homogeneous resins. In the opinion of many industry participants, the primary limitation on the development of these technologies is not current or potential market size, but assurance of a steady supply of the homogeneous resins. Developments in homogeneous resin processing technologies suggest that they will continue to be refined to yield products that are directly competitive with those made from virgin resins. These recycled products should be cost-competitive in appropriate markets.(EPA,1990/Barham,1991)

As pointed out in Section 6, such processes have employed primarily homogeneous resins recovered from PET/HDPE beverage containers and HDPE milk jugs being collected. **Table 10** presents a number of the products currently made from recycled PET and HDPE, including fiber (carpeting, fiberfill, and strapping), pipe and non-food containers, with estimates of the size of current and projected markets for these products.

Table 10 - Estimated markets for recycled plastic resins

Polyethylene Terephthalate	Market Size		High-Density Polyethylene	Market Size	
Product Applications	1987	1992	Product Applications	1987	1992
Fiber	90	180	Bottles (nonfood)	--	115
Injection molding	25	160	Drums	--	25
Extrusion	25	130	Pails	20	65
Non-food grade containers	--	30	Toys	--	15
Structural foam molding	--	30	Pipe	30	80
Paints, polyols, other chemical uses	10	20	Sheet	--	25
			Crates, cases, pallets	--	105
Stampable sheet	--	30	All other	4	130
Other	--	10			
Total-PET	150	590	Total-HDPE	54	560

Unit : millions of pounds, Source : EPA,1990

(iii)Markets for secondary technologies using mixed resins

Current mixed-resin secondary processing technologies yield products that are competitive with relatively low cost commodities. Their long-term marketing outlook may depend on technological developments that allow the production of high-quality, high-value products.(EPA,1990) **Table 11** provides quantitative estimates of the potential markets for a number of products of mixed-resin processing technologies.

Table 11 – Current and potential markets for mixed-resin recycled product

Market	Key Consideration	Market Outlook
Boat docks	Continuous exposure to harsh, wet environment Plastic products currently used, accepted	Strong regional potential
Park benches	Continued exposure to inclement weather	Strong potential
Horse stalls	Top and bottom rails subject to deterioration ideal for plastic	Strong regional potential
Railroad ties	Harsh outdoor environment suitable for plastics	Potential large market Tight construction specifications Depends on results of ongoing long-term strength tests
Auto curb stops	Plastic currently used, cost effective Coloring throughout saves maintenance costs compared to concrete alternatives	Limited data available
Breakwaters	Wet environment ideal for plastic	Tight construction regulations Regional markets only
Playground equipment	Outdoor environment ideal for plastic	Tight construction specifications

Source : EPA, 1990

For the plastic-recycling industry, it is difficult to develop an estimate for mixed plastics. A number of firms are already involved in this segment of the business, making products such as car stops for parking lots, park benches and pallets. These are new applications, where the recycled plastics, so-called "plastic lumber," are substituted for more traditional materials such as wood. CPRR has estimated that the market for recovered plastic products in noncritical landscape timber applications could reach 500 million pounds. According to CPRR, just a one percent penetration into the wood pallet market by plastics would consume 370 million pounds of mixed plastics in 1990.(Schell,1989)

Economic barriers currently impede further market penetration for many recycled products using mixed resins. For example, "plastic lumber may have an initial sales price 50 to 300 percent higher than comparable wood items, although lifecycle savings attributable to nonbiodegradability of plastic items may reduce or reverse this cost differential over the product lifetime. The long-term savings may be insufficient to overcome resistance to the high purchase price for many consumers. These barriers may be reduced as the processing technologies mature. A number of American research institutions, including the Plastics Recycling Foundation and CPRR, as well as a number of foreign firms and government agencies, are conducting active R&D programs to increase the applicability, reduce costs, and increase product quality for mixed-resin recycled products. This high level of commitment to additional research promises to significantly expand the market opportunities for these products in coming years." (EPA,1990)

(iv)Markets for products of tertiary processing technologies

"Markets for tertiary-recycled-plastic products vary with the process inputs. Products of tertiary processes using mixed resins represent a generally complex mixture of hydrocarbons. It is infeasible to refine such mixtures into pure product streams economically competitive with those obtained from processing petroleum or natural gas, and so these products are generally useful only as fuels. If recycling outputs are put to no other use, tertiary processing is no more than a synonym for incineration." (EPA,1990)

The products of tertiary processes using homogeneous, well-characterized resins, on the other hand, can be controlled and may be economically competitive with the products of refining processes. For example, tertiary processing of PET may produce chemical feedstocks of equal quality to and at lower prices than those obtained from raw refining processes. To date, tertiary processes that can convert homogeneous resin streams into high-quality chemical feedstocks have been developed in only a small number of installations in the U.S. Although limited evidence indicates that these plants have been economically viable, little research has been conducted into the potential long-term market for these tertiary recycled products.(EPA,1990)

(v)Uses for food packaging regulated by FDA

It is generally agreed in the U.S. that recycled plastic, regardless of its purity or properties, will not find use in food contact applications. Though the Food and Drug Administration (FDA) does not specifically prohibit the use of recycled plastics, the requirements to document purity and the potential liability in case of contamination are seen as prohibitive. There have been some suggestions for use as buried layers in food containers (as is already done for in-house scrap), but this has not yet been attempted for post-consumer plastics.(Selke,1988) Placing post-consumer PET back into new food or beverage containers has not occurred because of :

* Concern with consumer safety and compliance with FDA regulations.
* Absence of proven technologies to assure the safe use of post-consumer PET.(Barham,1991)

"For the FDA issue, Jerry Heckman, legal counsel to SPI, has stated many times that packagers need no special FDA clearance to use post-consumer PET for food as long as they can prove it is not contaminated and as long as the original material was cleared under FDA regulations. Indeed, the venture received the FDA stamp of approval January 10, 1991." (Barham,1991) This is a simple statement, but complicated by the potential problem with plastics - that is, they can absorb contaminants. The problem is further aggravated by the expectation that contaminants would not only include break-down products of beverage residues but also other foreign materials from the consumer use of empty plastic containers as storage vessels for household chemicals (e.g. oil, pesticides).(Barham,1991)

One approach to resolve these concerns has been the promotion of tertiary

recycling for PET. Tertiary recycling can be broadly defined as potentially reversing the polymerization chemical reaction and returning PET to its raw materials. These raw materials can be reacted to produce new PET for use in a number of applications, including new food and beverage containers. For this polymerization category, there are currently three processes :
* Methanolysis (Total depolymerization by methanol)
* Glycolysis (Partial depolymerization by ethylene glycol)
* Hydrolysis (Total depolymerization by water) (Barham,1991)

Section 8. Environmental Issues

Plastic recycling seems to have no significantly deleterious influence on the environment. "No known major environmental considerations impact the potentiality of plastic recycling as an alternative to reduce plastic disposal requirements. Collection and separation alternatives impose a variety of minor environmental costs, consisting primarily of energy use requirements related to recyclable collection, storage, and transportation (e.g., energy consumed by vehicles involved in a curbside recycling program)."(EPA,1990)

(i)Homogeneous-resin secondary processing alternative

This alternative generates environmental releases that are similar to those related to virgin plastic processing. "Environmental impacts should be no greater than those associated with production of equal volumes of virgin plastic products and, because they employ existing resins as inputs, should be less than for virgin resin manufacturing."(EPA,1990)

(ii)Mixed-resin secondary processing alternative

This process employs very mild conditions and produces minimal air and water pollution. "Acid gas emissions are produced by some mixed resin processes, but these can be controlled with proven scrubbing technologies. One relevant long-term environmental consideration is that because they do not displace consumption of virgin resins and because they may not eliminate the ultimate disposal requirement for their plastic constituents. Rather, use of mixed resin secondary processes delays that disposal requirement for the lifetime of recycled products. For this reason, the environmental benefits of mixed-resin processing should be measured in terms of deferring, rather than eliminating, plastic disposal and its associated environmental consequences."(EPA,1990)

(iii)Mixed-waste tertiary recycling processes

"This alternative produces a residual solid char (consisting primarily of carbon and ash) that must be disposed of; no toxicity testing has been performed on this substance. Tertiary processes employing homogeneous plastics with few additives produce little or no solid residue, however. Tertiary recycling products used as fuels produce emissions that should be compared to those of competing fossil fuels; no available evidence suggests that these emissions produce environmental impacts that are different from those associated with fossil fuel consumption."(EPA,1990)

Section 9. Outlook for plastic recycling

(i)Development efforts

Post-consumer plastic packaging, especially solid waste, appears to have been the target of increasing pressure by legislative bodies. Mandatory recycling for plastic containers is one example of this type of legislation. Efforts by plastic-packaging-related industries to promote the recyclability of plastics, as evidenced by the formation of the Plastics Recycling Foundation, are expected to increase, in large part to ward off the threat of adverse legislation. Business opportunities for entrepreneurs in plastic recycling are also expected to grow.(Selke,1988)

"New developments in all phases of plastic recycling are reported almost monthly. The very rapid recent progress both in technological innovation and in governmental support for plastic recycling augurs well for the continuing success of this waste management alternative. It is very difficult to predict the future of plastic recycling because so much depends on the research and other efforts that are now underway."(EPA,1990)

The infrastructure to collect and process rigid plastic containers has already begun to develop. Unfortunately, these results will most likely yield an overall plastic-packaging recycling rate of less than 10 percent. Given the negative opinion the public has concerning plastics in the waste stream, these results will probably not be good enough to avert new State and local bans directed at plastic packaging. Only by developing markets and processing technologies that utilize mixed resins can the plastic-packaging recycling rate exceed 10 percent in the early Nineties.(Schell,1989)

(ii)Du Pont recycling projects

Du Pont has recently announced several recycling projects as part of its ongoing efforts to help solve the solid waste problem.(Stuart,1990)

"Du Pont and American National Can signed an agreement on September 25, 1990, to cooperate in a program that will encourage the recycling of rigid multilayered plastic bottles not now being widely recycled. The first demonstration of this cooperative development is expected to occur in Chicago by early 1991. Chicago was selected because of the existing facility of the Plastic Recycling Alliance (PRA), a joint venture between Du Pont and Waste Management, Inc. The new agreement will involve the joint development of plastic sorting technology through the PRA as well as the development of fenduse markets for all grades of plastics."(Stuart,1990)

"PRA's recycling capability will be expanded from its current stream of PET soda bottles and HDPE milk jugs and laundry detergent bottles. Rigid multilayered plastics will be collected by Waste Management. PRA will process the collected containers into a form for use in the joint development program between American National Can and Du Pont." (Stuart,1990)

"In related news, Du Pont Canada and Procter & Gamble Canada announced a program, on August 22, 1990, to recycle post-consumer plastic for use in new bottles of Procter & Gamble's liquid laundry and cleaning products. Under the program, containers made of HDPE will be sorted, ground into flake, washed, dried, and packaged by PRA. The recycled material then will be supplied by Du Pont in a form usable by Procter & Gamble Canada's bottle supplier to make into packages for laundry and cleaning liquids marketed in Canada. This comprehensive program underscores Du Pont's commitment to making quality recycled plastic resins a reality."(Stuart,1990)

(iii)Political conflict between plastic recycling and use of degradable plastics

A possible policy conflict exists between recycling programs and the use of degradable plastics.(EPA,1990) Examples for the use of degradable plastics include the current proposal in the US Congress to ban non-biodegradable six-pack beverage container bundling devices, and activities at State levels to ban non-biodegradable fast-food packaging. (Selke,1988) Given the existing concerns about the purity of recycled resins, further contamination with degradable materials is problematic. Identification and separation of these degradable plastics, however, may weaken the economic basis of recycling methods. Thus, policy makers may have to choose whether to emphasize recycling or use of degradable plastics, and they will also need to identify which strategies will be employed for which products.(EPA,1990)

Section 10. Initialization of plastic recycling in Japan

(i)Incineration of plastic wastes

At the present time, most PET beverage bottles are disposed of in waste streams and then incinerated to utilize their heat energy instead of recycling, although current data on incineration or recycling rates for PET bottles are not available.(NKS,1991d) New types of incinerators which can combust a variety of plastic wastes without any toxic byproducts are increasingly utilized in municipalities, where those incinerators can supply residents and businesses with heat energy generated by their combustion in an effort to help the facility in a municipality to boil water and generate electricity. The technologies related to combustion of plastic wastes in incinerators have been already established and in fact any toxic materials are not produced in incineration of plastic wastes thanks to those state-of-the-art technologies. From a standpoint of environmental protection, incineration of plastic wastes used to be hazardous due to their byproducts being harmful to human health and environment, however, it is time for post-consumer plastics to be reconsidered as one of the significant resources of waste-to-energy programs.(NKS,1990)

(ii)Increasing demand for PET bottles

Amount of PET consumption in Japan, especially PET bottles used for soft drinks, has been steadily increasing since the middle of the 1980s. The number of PET beverage bottles produced currently in Japan ranges from 1 to 2 billion per year.(NKS,1991d) Approximately 120,000 tons of PET resins were consumed last year, however, only a negligible part of post-consumer bottles have been recycled by some municipalities. Trend of demand for PET resin which is used for bottles in fields of beverage, foods and non-foods such as detergents, shampoos, cosmetics and pharmaceutical products in Japan is shown below (see **Figure 5**).(PBCS,1991) Demand for soft-drink bottles has been constantly increasing since the beginning of the 1980's. On the other hand, demands for other uses, such as sauce, alcohol, and non-foods, have kept level during these years. Markets of packaging for non-foods including household detergent, shampoo, and cosmetics are fully matured and will apparently be unable to expand to a certain extent in spite of manufacturers efforts. The beer industry used to put its efforts into developing new styles of PET containers in accordance with its marketing strategies; however, it recently has shifted its main stream of beer sales to aluminum cans.

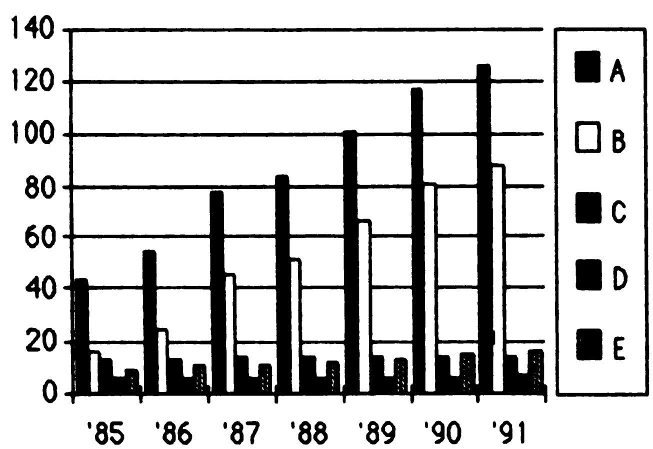

Figure 5 - Demands for PET resin used for bottles in Japan (1985 - 1991)
A:Grand total, B:Soft drinks, C:Soy, sauce, D:Alcohol, E:Non-foods
Figures in 1991 : projection, Unit : 1,000 metric tons, Source : PBCS,1991

(iii)Industry's activities regarding PET bottles

The beverage industry, including beer, milk, soda and other soft drinks have cooperated with each other for self-restraint to a lower quantity level of production of small-sized portion packaging made from PET resins for the sake of decreasing to a certain extent post-consumer plastic wastes in solid waste stream, although legislation forcing those industries to do so does not exist so far.(NKS,1991d)

On the other hand, the industry group of Mitsui, which includes several companies of the largest suppliers of PET resins and products in Japan, is now planning to do a feasibility study on a recycling business for PET beverage bottles.(NKS,1991d)

PART FIVE
SUMMARY AND CONCLUSIONS

This part includes two chapters such as characteristics of recycling in Japan and recommended recycling systems in the country as the conclusions of this thesis.

As described in previous chapters, there are literally hundreds of combinations of specific program parameters that can be considered when planning for integrated recycling programs in Japan. The planners need to make a decision on a wide range of issues such as which materials to collect, who and how to collect them, how to separate them, how to process them, how to determine all associated costs and expected revenues, how to encourage use of secondary raw materials as well as recycled products, and how to maximize public participation rate.

The purpose of this part is to choose conclusive elements for promoting growth of recycling systems suitable to Japan among potential alternatives which have been discussed in preceding chapters, taking into account a number of characteristics of Japan's recent situation relevant to recycling. It is important to research the advantages and disadvantages of a great deal of variable parameters in each phase of integrated recycling systems, and forecast the possibilities with regard to various types of trade-offs among them when determining the recycling systems to be adopted in Japan.

Chapter 12. Characteristics of Recycling in Japan

It is forecasted that businesses related to recycling in Japan will be growing, subject to the availability of appropriate legislation and systems to effectively implement recycling activities, from the current 30 billion dollars to 75 billion dollars in the near future.(NKS,1991a) In Japan, however, there has not been a combination of various recycling systems, such as container deposit laws and curbside pickup, that is now underway in the U.S.A. Recently, in Japan as well as the U.S.A., national and local governments, especially large cities like Tokyo, have seriously considered the solid waste management as a critical issue for the country to flourish. The following paragraphs will be helpful for understanding features of the nationwide recycling activities, efforts by governmental agencies, and critical condition in the Tokyo metropolitan area.

Section 1. Japan's current solid waste management situation

(1)Classification of solid waste materials

According to statistical research conducted by the Ministry of Health and Welfare, separated collection of flammable wastes from non-flammable ones is now underway. However, it is estimated that only 21 percent of all municipalities throughout Japan operated the collection programs in the fiscal year of 1988.

MSW in the country is generally divided into the following categories, as shown in **Table 12**, in accordance with features of each item including where it is generated, burnable or unburnable, end-use, and size. Industrial wastes mean unwanted materials produced in or eliminated from industrial manufacturing processes.

Table 12 - Classification of solid waste materials in Japan

(I) Non-industrial solid wastes (gross generated quantity : 46)

(A) Home-related

1. Combustibles (paper, plastic, rubber, etc.)
2. Non-combustibles or unsuitable materials for incineration (metal, glass, dry cell)
3. Large wastes (appliance, furniture, etc.)
4. Packaging (aluminum cans, steel cans, glass bottles, etc.)

(B) Office-related (computer paper, fax paper, etc.)

(II) Industrial solid wastes (gross generated quantity : 253)
(finally disposed quantity : 36)

1. Liquid wastes
2. Solid wastes
3. Sludge wastes

Unit : million metric tons, Source : NKS,1991a

(ii)Bills presented by governmental agencies

According to a recent survey conducted by the Ministry of Health and Welfare, Japan has space for burying waste only for another eight years for domestic non-industrial wastes and one and a half years for industrial wastes. To cope with the nationwide waste crisis, the Japanese government recently presented two related bills to the current Diet session and legislators are now debating them.(JEJ,1991)

1. The Ministry of International Trade and Industry (MITI)

The MITI drafted a bill, which promotes recycling of industrial wastes and also of by-products, and urges manufacturers to use recycled resources in production.(JEJ,1991) The bill finally passed in 1991.

The MITI indicated that manufacturers and distribution industries have to implement the following matters in an effort to support environmental protection ;

(1) to use materials which can be easily recycled and to adopt appropriate industrial structures,

(2) to reuse and recycle byproducts such as metal or plastic scraps, and

(3) to recycle computer papers generated in their offices and factories.

MITI's bill urges manufacturers to design products with recycling in mind.

To facilitate separation of waste collected for recycling, the bill requires manufacturers to detail the composition of their products.(JEJ,1991)

Although concrete regulations are not likely to emerge for another six months, penalties for companies which do not fulfill MITI's requirements under the new law will range up to Yen 500,000.(JEJ,1991)

2. The Ministry of Health and Welfare

The Ministry of Health and Welfare has drafted a revision of the Waste Disposal and Public Cleaning Law which requires municipal authorities to request private sector cooperation in the disposal of post-consumer products, although the extent of cooperation will be up to the companies themselves.

The ministry initially intended to require business enterprises to take the responsibility for disposing of waste paper, in order to promote recycling. Waste paper is currently collected and disposed of by municipal authorities. However under the revised bill, owners of buildings are only required to draft plans for waste paper disposal. Initially, the ministry had considered requiring manufacturers to shoulder the costs for disposal of their products, but apparently abandoned the idea due to opposition from MITI and the industry concerned.(JEJ,1991)

On the other hand, some industries are falling in step with the government's campaign to tackle the waste crisis. The furniture industry, for example, plans a nationwide scheme to start to collect used office furniture. The Japan Office and Institutional Furniture Association, comprising 98 firms out of some 400 companies in Japan, will accept all kinds of used furniture including items produced by non-member companies. The association will also develop techniques for manufacturing products which can be easily recycled and also plans to promote waste disposal technology. It is apparently a fundamental concept for the association that manufacturers cannot boost sales of new products without solving the problems of waste disposal.(JEJ,1991)

Automakers will also share responsibility for industrial waste disposal. According to the Japan Automobile Manufacturers Association Inc. (JAMA), car makers will pay disposal costs for unwanted cars which are dumped on roadsides. Currently disposal costs for such vehicles are paid by municipal authorities. The JAMA will start its service from April in 1991.(JEJ,1991)

In addition to the above two ministries, other governmental agencies are also now attempting to establish their own efficient plans for municipal solid waste management, which are shown below.

3. The Industrial Council

The Industrial Council set up a guideline for solid waste management and promotion methods for reuse and recycling. The outline is as follows, although the concern is limited to only non-industrial wastes;
(1) industries, consumers, and local governments should cooperate in recycling and reducing through nationwide activities, (2) local governments and municipalities should establish cooperative systems, and (3) waste-to-energy measures should be promoted.

4. The Environmental Agency

This governmental agency, which is similar to EPA in the U.S., argued that those people who have been accustomed to fortunate lifestyles, that are enabled by an abundance of commercial products, should now remember their negative effects on environmental conservation and reconsider the benefits of recycling and a resource-reduction oriented social life. It is expected that the public will attempt to improve entire social systems that lead to mass production, mass consumption and as a result mass disposal of post-consumer wastes.(NKS,1991a) The Environmental Agency had initially drafted a similar bill to MITI's, although it dealt more generally with environmental protection. However, it has now been incorporated into MITI's bill.(JEJ,1991)

(iii)Littering

Littering used empty cans tends not to reduce, according to current Environmental Agency research. The number of cans littered on main traffic roadsides in 1990 was 2.4 cans per 100 meters per day, which is higher than 2.3 cans of the previous year's figure (see **Table 13**).(NKS,1991b)

Table 13 - The number of cans littered on roadsides in Japan (1989, 1990)

	1989	1990
Main national traffic roadsides (cans per 100 meters per day)	2.3	2.4
Ordinary traffic roadsides (cans per 100 meters per day)	1.8	1.6
Mountain trails (cans per 100 meters per day)	0.4	0.5
Sea and lake shores (cans per 1000 sq. meters per day)	1.9	2.1
River sides (cans per 1000 sq. meters per day)	1.9	2.0

Source : NKS, 1991b

(iv)Environmental consciousness of consumers and industries

Most Japanese consumers are just as interested in issues concerning environmental protection as Americans and Germans. They are just less willing to pay for it, according to a recent survey conducted by the Nikkei Marketing Journal, published by Nihon Keizai Shimbun Inc.(JEJ, 1990b)

"The random-sample survey was conducted from mid-April through early May. Some 2,000 people aged 20-69 were polled in and around Tokyo, New York and Frankfurt; 957 responded in Tokyo, 102 in New York and 104 in Frankfurt. The survey found that over 90 percent of respondents in each of three cities - Tokyo, New York and Frankfurt - believed consumers have to take the problem of environmental protection more seriously. The same number said businesses should not produce goods that harm the environment."(JEJ, 1990b)

As mentioned earlier, for environmental activities of Japanese industries, a number of sections or committees specializing in the environment have recently set up, or plan to form. These groups are designed to help their companies deal with the prospect of stricter environmental regulations at home and abroad. In addition, as "green power" is spreading, they also function to shore up the corporate image and to help find business opportunities related to environmental technology and products.(JEJ, 1990a)

Section 2. Tokyo's garbage crisis

(1)Waste problems and resolution efforts

Amid the nation's growing waste disposal crisis, the Tokyo Metropolitan government is launching a "Clean-up Tokyo" campaign which includes putting posters in railway stations and organizing educational events. Although waste disposal is seen as a nationwide problem, Tokyo is in the most serious situation.(JEJ,1991)

Non-industrial waste in Tokyo increases at rate of approximately 5 percent every year and as a result all facilities for landfilling, incinerating and recycling are operated at full capacity. About 9,000 tons of refuse is carried daily to disposal sites in Tokyo Bay. In fiscal 1989, the Tokyo government dealt with a total 4,901,000 tons of waste, up by 118,000 tons from the previous year. Included in the waste, a total 124,042 television sets, 98,716 refrigerators and 84,408 washing machines were disposed of in the metropolitan area alone, according to Tokyo government figures. In order to expand waste disposal capacity, the Tokyo government plans to build on its "garbage islands" scheme in Tokyo Bay.(JEJ,1991)

Tokyo metropolitan government and the Ministry of International Trade and Industry (MITI) are jointly launching aluminum UBC recycling programs. Tokyo local government and MITI are planning to cooperate with each other to set up dropoff recycling sites to collect aluminum UBC in the Tokyo metropolitan area. These sites will be located at not only supermarkets and gas stations but also multi-family dwellings, and facilitated by recycling equipment such as press machines and reverse vending machines. It will be obviously correct that the dropoff sites are easily accessible and convenient for participants because consumers need not to pay deposit nor spend time and money transporting UBC to remote recycling centers.

Tokyo local government and MITI have already established an association to promote aluminum UBC recycling programs and they are aiming at increasing recycling rate for aluminum UBC from the current approximately 40 percent to 60 percent in a few years. The association involves 37 private enterprises related to recycling systems such as aluminum can producers, distributors, retailers, soft drink companies, and collection industry. The association is expected to forecast the volume of aluminum UBC which would be collected and the number of households which will be covered by one collection site, and develop processing technologies for removing steel, paper, and other contaminants from aluminum.(NKS,1991e)

For recycling firms, on the other hand, it has been increasingly difficult for them to obtain or keep their processing plant and stock yard in suburbs of large cities due to current appreciation of both land price and labor cost.(NKS,1991b) In big cities such as Tokyo and Osaka, collecting firms must store a number of recyclables on high-priced floor space. Some of them are compelled to go out of business due to the economic burdens. (NKS,1991f) This contrasts with the situation in the U.S.A. As noticed earlier, in the U.S.A., it is expected to see a shift in plant sitings, from rural areas (where labor and overhead costs are low) to urban areas closer to the sources of the secondary raw materials. On the other hand, the number of collectors in Tokyo has dramatically decreased since the 1960s and that in Osaka, which is the second largest city in Japan, has remained at the same level as 1975 (see **Figure 6**).

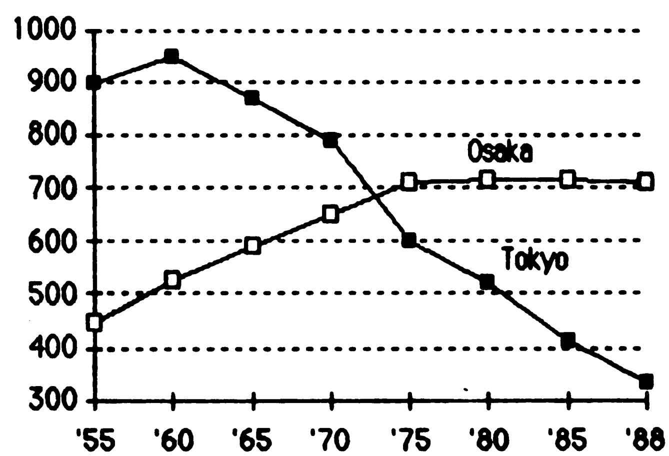

Figure 6 - Collecting agencies in Tokyo and Osaka (1955 - 1988)
Source : MPA,1991

Economic activity in the Tokyo metropolitan area has continued to grow since the fiscal year of 1981, and recently gross production in the area made up nearly 20 percent of Japan's gross domestic production (GDP) according to Tokyo local government official reports. Comparing the figures of Tokyo with those in nations which belong to OECD, Tokyo will be equal to the seventh largest 'country' and followed by Canada, Spain, and so forth (see **Figure 7**). Both industrial and non-industrial waste streams tend to increase as production and consumption increase. Nevertheless, many waste carters and dealers have had to go out of business in the metropolitan area, because extremely high land prices interrupt the waste businesses who generally do not have sufficient capital. This phenomenon should be one of the critical problems for waste management in Tokyo.

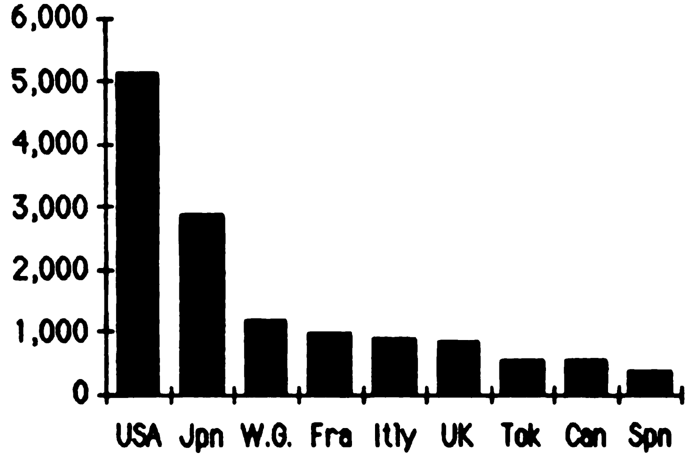

Figure 7 - Gross production in the Tokyo metropolitan area
Unit : billion dollars, Source : OECD, National Accounts, 1991
The analysis is based on data in 1989.

Local governments and civic organizations have been increasingly concerned with recycling and reuse of resources due to the current crisis of solid waste management in large cities, especially Tokyo.

The Tokyo local government attempts to promote recycling programs through renting reverse-vending machines that can supply users with one yen per used can, either steel or aluminum, to major public utilities such as community gymnasiums and libraries in which the public at large may frequently use vending machines of soft drinks. They can automatically segregate those two types of cans and press them and finally store them inside the machines. The location of the reverse-vending machines will be very convenient for the public and as a result participation may increase as the local government expects.(NKS,1991g)

As far as municipalities are concerned, those residents who are not interested in local volunteer activities such as recycling and keeping local areas clean have been increasing because a great number of newcomers have moved into suburbs surrounding large cities. On the contrary, the actual number of those who can be engaged in the local volunteer activities have been decreasing because elderly people have been relatively increasing and lots of householders tend to work outside of their homes during the day. (NKS,1991b)

A Tokyo metropolitan government official who is welcoming the government's moves as an initial step commented as follows : "Most of the waste we collect every day includes useful things. Recycling also needs energy. What we have to do now is actually cut down the waste."(JEJ,1991)

(ii)Comparison with the case of New York State

Paper and paperboard account for more than 50 percent of all packaging materials by weight. Glass, metals, plastics and wood account for the remainder. Approximately nine-tenths of all packaging materials consumed are discarded each year. Although per capita generation of packaging waste has increased steadily, reflecting the expansion of our economy (approximately 1,200 new products are introduced into the marketplace each year), the overall percentage of packaging waste in the solid waste stream has decreased slightly due to the increase in use of aluminum and plastics which are lighter than other packaging materials. **Table 14** illustrates the increase in packaging waste.(NYS,1988)

Table 14 - Packaging use and waste packaging generation in the State of New York

(1)Per Capita Consumption of Packaging Material (lbs.)
(2)Per Capita Packaging Waste Generated (lbs.)
(3)Quantity of Packaging Waste Generated (million tons)

Year	(1)	(2)	(3)
1958	404	360	2.7
1966	525	477	3.4
1976	661	594	5.2
1986*	800	720	6.5

*Projection based on continued rate of increase at same rate for 1976-86 as for 1966-76.

Source : NYS,1988

Section 3. Impacts of target rates on waste management

In both the U.S.A. and Japan, governmental agencies and the industries concerned with recycling have set goals that specify minimum levels for recycling percentages of the solid waste stream. The following discussion will focus on impacts of the target rates on waste management.

(i)In the case of New York State

In the case of New York State, the government set the State's goal of a combined waste reduction and recycling rate of 50 percent by weight by 1997. Although not a regulatory requirement, this goal represents what DEC believes to be a reasonable and achievable overall combined rate. DEC does not expect all new recycling programs to achieve significant recycling rates immediately. As recycling programs mature and markets for recycled materials expand, DEC does expect a steady increase in individual program recycling rates.(NYS,1988)

On the other hand, the 50 percent reduction/recycling goal will have an important impact on sizing and evaluating future MSW management facilities. Plans to construct waste management facilities will need to consider the expected decrease in the MSW stream resulting from waste reduction and recycling. They will also need to consider how to construct the facilities in units which can be phased out or used as back up units when recycling reaches its full potential.(NYS,1988)

(ii)Goals set by a governmental agency, MITI

According to research conducted by both Economic Planning Association and Environmental Agency, in Japan, expanded efforts for recycling of four kinds of products, including aluminum and steel cans, glass containers and paper, would be able to reduce energy consumption by 1.41 million kilo-liters of oil in the year of 2000, and by 3.81 million kiloliters in 2010. Although recycling would be an extremely effective measure for energy saving and resource conservation, expansion of recycling activities may not be so optimistic. For example, aluminum and steel UBC are recycled at about 40 percent at the present time which has been unchanged in recent years. These recycling rates of aluminum cans are obviously lower than those in the U.S.A., which is said to be more than 60 percent.(NKS,1990b)

In a bid to boost the use of recycled paper, MITI has set a target ratio of 55 percent recycled paper to total paper production for the fiscal year of 1994 - an increase from the 50 percent level reached in fiscal 1989.(JEJ,1991)

The ministry is also considering plans to set the ratios of recycled steel cans to 60 percent in 1995 from 44 percent in 1989, and recycled aluminum cans to 60 percent in fiscal 1994, up from 43 percent in fiscal 1989. (JEJ,1991)

(iii)Contrasting targets in both countries

In Japan, MITI set the goals of recycling rates for steel, aluminum and newsprint. Municipalities all over the country have to put their efforts into accomplishing these targets, although they are not regulatory requirements. The MITI's goals will have a significant effect on sizing and evaluating future MSW management facilities. Nevertheless, in the case of Japan, these goals appear not to represent reasonable and achievable rates, because the figures, particularly for aluminum cans, are out of consistency in terms of growth from the past to the present time in recycling rates. For aluminum cans, the recycling rate is estimated at less than 45 percent at present, but the target rate is set to 60 percent for fiscal 1994. In addition, these recycling targets have not been self-developed by the beverage and aluminum-can industries.

According to Figure 2 in Chapter 10, the trend of recycling rate for aluminum UBC in the U.S.A. shows that it spent eight years increasing the rate from a level of 50 percent in 1981 to around 60 percent in 1989 and the recycling rate reached the highest level 63.6 percent in 1990. In California, it is estimated at 73 percent in 1989, which is very close to the 75 percent goal for the nation that the aluminum industry has set for 1995. The primary reason for the success of aluminum UBC recycling in the U.S.A. is the effort the aluminum industry has put into setting up the required network to successfully collect and reprocess the containers. The efficient nationwide networks for aluminum can recycling had been already founded in the 1970s.

In Japan, however, the efforts to set up the recycling systems are underway across the country. It appears that the target for aluminum UBC recycling is far from a realistic rate, because of a lack of infrastructure for the recycling system. Even if the number and scope of local recycling programs happens to increase during the next few years, it is likely to be impossible to achieve the MITI's goal. It will be hard to establish effective recycling programs within a few years, because a great range of methods suitable for the integrated recycling systems have to be chosen after serious studies and research on a long-term basis.

Chapter 13. Recommended recycling systems in Japan

Section 1. Strategies for encouraging public participation

Public participation rate appears to be the single most important variable determining overall net economic cost or benefit of collection alternatives. Communities must enlist the support of the population to accept recycling as part of the solution to the MSW problem and motivate them to do their part. The effective strategies for increasing public participation rates are discussed below.

(i)Education programs

In order to maximize public participation in recycling programs, it is usually necessary to initiate an education program. The education programs must be continual and help citizens understand the importance of recycling efforts to their communities and eventually themselves. The direct contact between the collector of recyclables and the generator of those materials is usually a key component of any effective program.

(ii)Convenience for participants

For most suburban settings in Japan, a great number of newcomers have moved into the suburbs surrounding large cities and they are not interested in local volunteer activities such as recycling have been increasing. In addition, the actual number of those who can not be actively engaged in the local volunteer activities have been increasing, because elderly people have been relatively increasing and lots of householders tend to work outside of their homes during the day. On the other hand, in urban areas such as the Tokyo metropolitan area, the number of private collectors has dramatically decreased. Therefore, in the suburban areas as well as urban areas, convenience for participants has become a significantly important factor to success for the collection programs.

(iii)Establishment of effective incentives by government

It is necessary for national and local governments to establish effective incentives for encouraging consumers to participate in recycling programs.

For consumers, economic incentives seem to be preferable to tax credits as a means of promoting recycling. Methods for implementing the incentives include a reward and a garbage service charge that would give participants a financial incentive according to the level of their recycling efforts.

Section 2. Effectiveness of incentives for industry

Local governments in Japan should investigate the feasibility of utilizing economic development offices, which are designed to provide a variety of economic and political advantages, such as tax incentives, financial benefits, siting and zoning assistance, to attract new businesses and to help existing companies to expand. However, it may not be always true in any cases that these advantages can directly effect positive participation of the businesses.

Section 3. Recommended collection alternatives

As pointed out in Part One, each collection option has a number of its own advantages and disadvantages in terms of economic efficiency, convenience for participants, quality of collected recyclable materials, viability for various types of areas and municipalities, and effectiveness for increasing participation rates of residents and industries.

There are a number of municipalities, in Japan as well as the U.S.A., ranging from rural areas with few multi-family dwellings to large cities, such as Tokyo and Osaka, with a extremely high level of population density. On the other hand, one collection method may be suitable to not the rural areas, but the urban areas. The other method may be an opposite case to it and there may exist another option that can be viable to any type of area. Therefore, it will be nationally effective for achieving high participation rates in recycling programs that each community independently implements the collection methods suitable to the characteristics of the community.

The following discussion will focus on recommendations for alternative collection methods in accordance with the type of a community in Japan.

(1)At initial stage for a community's recycling

Dropoff centers may be a successful recycling option at initial stage for a community's recycling. Where a community is just becoming involved in recycling, the development of a dropoff program can provide officials with a relatively inexpensive learning experience.

(ii)In rural areas with a low density of population

In rural areas with a low density of population, especially with no centralized MSW collection services, container deposit legislation and drop-off site programs may be preferable to curbside pick-up programs, because the demographic characteristics of the areas can militate against the successful widespread use of curbside collection. Deposit legislation and drop-off programs can provide MRFs with post-consumer aluminum and plastic beverage containers of relatively high quality.

(iii)In suburban settings with few multi-family dwellings

Curbside collection programs are likely to be successfully operated in suburban settings with few multi-family dwellings in Japan as well as the U.S.A., subject to implementation of the following essential issues :

* The planners of curbside collection programs should keep in mind that the fundamental concept in a residential program is simplicity, that is one collection day, one container, and collection on the same day as collection of other MSW.
* Local governments should provide residents in the program with recycling containers for convenience, reminders and as a peer pressure tool.
* Increasing collection frequency, for example, from biweekly to weekly collection, usually appears to increase yields of recyclables, because the added convenience by providing more frequent collection will remove the need for long-term storage of the recyclables and result in stimulating the public participation. In Japan, since storing a number of classes of recyclables will apparently become a burden on those participants who live in small houses or multi-family dwellings, a monthly collection will tend to reduce participation rates in recycling programs to a great extent.

(iv)In urban areas with large numbers of multi-family residences

Curbside programs may face significant hurdles to implementation in urban environments with a great density of population and large numbers of multi-family residences. In Japan as well as the U.S.A., curbside programs seem to have less effectiveness in diverting a great deal of recyclables from MSW stream in urban areas than such collection alternatives as deposit laws and reverse-vending machines.

For multi-family dwellings including apartments and condominiums in most large cities, such as Tokyo and Osaka, a full-time apartment recycling coordinator may be helpful to develop and implement the recycling program. The coordinator is responsible for informing apartment owners, managers and dwellers how to recycle, promoting the availability of the program, and for coordinating information between the recyclers and apartment building owners, managers and tenants. Diversion credit programs in which a community pays private recyclers for recyclable materials that they divert from the multi-family building waste stream may be a way to provide a variety of recycling services to multi-family buildings.

(v)Recommended collection options regardless of setting types

For both aluminum UBC and plastic containers, reverse-vending machines are likely to become much more prevalent as an collection option in support of other collection alternatives. This option has economic incentives and also convenience for consumers.

Comprehensive recycling programs, such as curbside pickup and drop-off centers, and discriminative programs, such as container deposit laws and reverse-vending machines, are likely not to be mutually exclusive in any type of area.

For plastics, while curbside collection may target either specific plastic containers or a variety of plastics, this option seems to have a potentiality to become a major supply factor for mixed resins, rather than homogeneous resins. On the other hand, container deposit legislation is very successful at capturing a large proportion of targeted plastic containers, yielding homogeneous recycled resins, such as PET and HDPE, amenable to high-value processing applications. However, this option typically affects only a very small proportion of MSW plastics. Especially if broadened to include additional categories of recyclable plastic items, it may tend to adversely impact the viability or success of curbside programs.

Therefore, a combination of curbside collection and deposit legislation may prove to be an effective recycling policy option for plastics. It would be more expensive for a community to operate both a deposit and a curbside program than only one of these. However, this combination can compensate for inferiorities of one collection option with superiorities of the other option. In most practicable implementation scenarios, while curbside programs collect a mixture of plastic wastes, deposit laws collect specific plastic beverage containers, such as PET bottles.

Section 4. Recommended source separations in curbside program

(i)In suburban areas with a high population density

Commingled storage at home will help to maximize public participation. In addition, this option has some clear advantages in terms of vehicle capacity utilization and time savings over curbside sort. These advantages will result in saving fuel cost substantially in Japan. However, this option needs an expensive MRF for separation of the commingled recyclables. Therefore, this strategy seems to be suitable for suburban areas with a relatively high density of population, where capital and operation costs per capita for the MRF will be a light burden for the residents.

Aluminum cans are able to be mechanically separated from steel/tin cans by a magnetic separator at MRFs. On the other hand, since mixed plastics can not be easily separated by resin type at MRFs with current technologies, this option is suitable to secondary processing methods employing mixed resins, instead of homogeneous resins.

(ii)In suburbs and rural areas

Curbside sorting needs not to develop and pay to operate a MRF, and enables residents to separate without worrying about multiple sorting. As the sorters separate recyclables from non-recyclables, they can perform a quality-control function. As a result, the separated materials are probably close to market specifications, although dependent on the training and performance of the collector. This option may be suitable to suburbs or rural areas with a low density of population, where expensive MRFs will be a heavy burden for the residents and mini-MRFs can be successfully operated from an economic viewpoint.

Section 5. Processing of collected aluminum and plastics

(i)Aluminum

Relatively homogeneous materials can be recovered in aluminum recycling, and this contrasts with recycled plastics which represent a mixed nature because a variety of plastic resins exist in the waste stream. However, multiple collection of recyclable materials will lead to decreased quality of the collected aluminum, because as many recyclables are commingled, the possibility of contamination increases.

In Japan, as pointed out earlier, the difficulty in manually separating aluminum cans from steel cans may be one of the significant reasons for the actual recycling rates for aluminum UBC having been at a level lower than expected. While aluminum and steel/tin cans are nearly indistinguishable, aluminum cans make up only one-third of the markets for metal beverage cans in Japan. As a result, it is hard to economically increase the number of aluminum UBC separated from a larger quantity of steel/tin cans, although cost of a magnetic can separator is relatively inexpensive.

In order to distinguish aluminum cans from steel/tin cans when manually collecting and processing them in MRFs, a voluntary labeling system for recyclable containers will be effective. This system is similar to the system instituted by the Society of the Plastics Industry (SPI) for recyclable plastics. In this case, the printed label contains a mark specifying the metal used for the can. These marks have been voluntarily adopted by much of the steel and aluminum processing industry and are currently beginning to appear on cans distributed in consumer markets in Japan. This label system will help development of curbside sorting option.

(ii)Plastics

Processing is much more important for plastics than for aluminum. Only homogeneous resin streams can be recycled into products that compete with virgin resins. All plastic recycling processes result in some degradation of the physical and chemical characteristics of the plastic resin(s). For this reason, recycled plastics may not be suitable to replace virgin resins in many applications with exacting product specifications, particularly in food-contact applications. However, with good separation into clean, homogeneous resins, recycled plastics may be used to make a broad range of products that would otherwise be fabricated from virgin resins, or may be incorporated into mixes with virgin resins in a variety of product applications. With current recycling technologies for mixed plastics, however, recycled resins are incorporated into products with less demanding physical characteristics, for which market competition comes not from virgin plastics but from other commodities like lumber or cement.

The mixed nature of most post-consumer plastics has significant influence on the methods adopted in plastic recycling programs. For example, as described earlier, in the case of a combination of curbside collection programs and container deposit legislation, the following processing or separation options may be respectively required : curbside programs imply that only mixed-plastic technologies will be available as processing options for the collected mixed plastics. On the other hand, deposit legislation demands that efficient plastic separation from nonplastics be implemented to allow the capture of homogeneous resins.

Section 6. Marketing of recycled products

For supply-limited materials, such as aluminum and homogeneous plastics, since the major barrier to recycling may be the lack of more effective collection programs, it is of importance to increase the amount of waste being collected. On the other hand, for demand-limited materials such as mixed plastics, new and expanded markets for them must be established to absorb the large volumes of materials required to divert from the MSW stream.

(i)Aluminum

Aluminum is one of the supply-limited recyclables in both the U.S.A. and Japan. Demand for aluminum scrap, especially UBC, is likely to increase in the future in both countries, because the beverage and food industries will require more quantities of aluminum cans than ever before due to expanding consumption of soft drinks, beer, and canned food. From an economic viewpoint, aluminum manufacturers like using recycled materials to make can sheet, because they net immense savings in energy costs, on the order of a 95 percent reduction. From an environmental viewpoint, on the other hand, it is estimated that air pollution is reduced by 95 percent and water pollution by 97 percent. Therefore, it is necessary to put efforts into developing more effective collection alternatives for aluminum UBC, rather than creating new end-markets or expanding existing markets for recycled products in Japan.

(ii)Plastics

For plastics, there are no foreseeable limitations on markets for products of technologies using clean, homogeneous recycled resins, but their deployment is currently constrained by limited supplies of the raw materials. On the other hand, demands for some types of recycled products processed by secondary technologies using mixed resins are limited to date, since they may not be suitable to replace virgin resins in many applications with exacting product specifications, such as a food-contact packaging.

Substantial markets are expected to exist for the products of secondary processes employing homogeneous-resin inputs and for some tertiary processing technologies, and market opportunities should not limit the growth of these technologies in the foreseeable future. The products of mixed-resin secondary processes, however, may face significant marketing challenges. These processes may need to overcome cost and product quality hurdles to be assured of adequate long-term markets. For instance, in packaging use, demand for recycled products processed by means of secondary technologies using mixed resins have been actually limited.

In Japan, the Ministry of Health and Welfare, which administers affairs of foods and drugs, has not yet determined specific standards concerning the use of recycled plastic products of secondary processes in food-contact applications. As a result, the food and beverage industries will need to continue self-restraint regarding growth of the plastic-container use, particularly PET bottles, for the time being.

For recycling of plastics to flourish in Japan on a long-term basis, at the initial step, it is important to place an emphasis on both creating markets for recycled products processed by secondary technologies using mixed resins, and establishing effective methods for collecting or separating homogeneous resins from a commingled waste stream. It will be necessary for success in recycling for homogeneous resins that the beverage and packaging industries should begin with feasibility studies in respect of PET bottle recycling business.

Section 7. Integration of recycling alternatives for plastics

One of the most notable characteristics of plastic recycling is the variety of alternatives available to implement each of the four phases of the recycling process. However, the choices among available alternatives for each phase are intricately interrelated. For example, implementation of mixed-plastic collection implies that only mixed-resin secondary recycling processes will be available for the recycled resins. However, the potentially larger markets and high value for homogeneous-resin products may simultaneously spur the development of effective resin separation technologies, ultimately allowing high-volume collection (i.e., collection of mixed plastics) to be coupled with homogeneous-resin recycling processes.

Combinations of collection and separation alternatives that tend to link capture of high volumes of plastics with output of homogeneous-resin streams are the most valuable in terms of opening the largest markets for recycled-plastic products and providing the greatest long-term diversion of plastics from MSW disposal requirements.

Section 8. Cost sharing among government, industry and resident

For recycling to be taken seriously as a disposal alternative, it must be reliable. This requires establishing an economic environment which can sustain it over the long term. From an economic viewpoint, resolution of a variety of cost relevant to recycling programs is essential for success. The cost should be shared among national and local governments, industries, institutions and residents in order to support implementation of recycling systems on a long-term basis. It might be acceptable for consumers to add an appropriate part of necessary costs for recycling in the retail price of a broad range of consumer products, including packed and canned foods and bottled beverages. On the other hand, for industries, the processing cost for post-consumer recyclables has to be considered as one of social cost and borne by the concerned industry, instead of easily passing the cost back to consumers, for example, in the form of higher beverage prices.

Industries and consumers used to have an opposing relationship between them with regard to matters of public pollution. Consumers claimed that industries should always take their responsibilities on causes of the pollution, however, they would pay little money as compensation for damage occurred by the pollution. On the other hand, industries opposed that consumers tend to blame them for all of the pollution without any scientifically proven reasons. However, the relationship between industries and consumers has been changing recently from opposition to cooperation. Consumers recognized that they should cooperate with industries in an effort to materialize their ideal plans and to implement environmental protection. Industries not only have to restructure their commercial activity, but consumers also have to change their purchasing activity in accordance with requirements of environmental conservation. The relationship between consumers and industries needs to keep strained in order to come up with realistic methods of environmental protection.

For the packaging industry, it is important that packaging professionals consider package disposal in the package design process. Disposal is most often an external cost at present, which is easy to overlook. However, the current packaging professionals have responsibilities for demonstrating a commitment to environmentally sound packaging. The additional costs for the environmental packaging should be shared between such industries as food, beverage and packaging, and consumers.

APPENDIX A

APPENDIX A

The following Figures (8 and 9) will help in understanding Japan's current situation relevant to bottled-beverage production and steel can recycling.

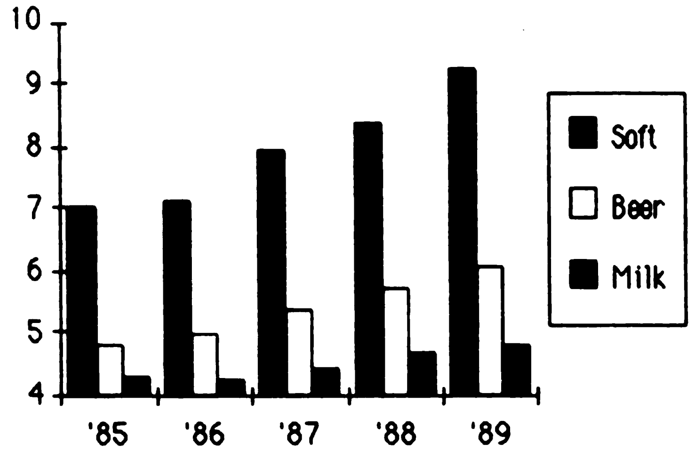

Figure 8 - Production volume of bottled beverages in Japan (1985 - 1989)
Unit: million kiloliters, Source : Yoshino, 1991

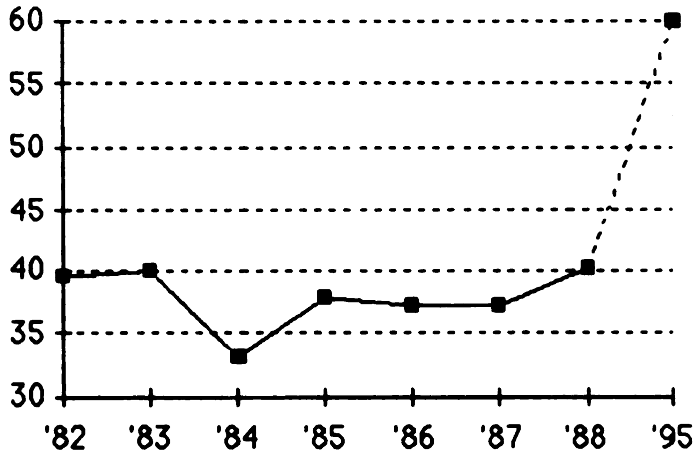

Figure 9 - Change in the recycling rates for steel cans and target rate in Japan (1982 - 1988, 1995)
Unit : %, Source : JUTA, 1990

APPENDIX B

APPENDIX B

The following Tables (15 and 16) will help in understanding recent plastic consumption situation relevant to packaging in the U.S.A.

Table 15 - Plastic packaging materials in the USA (1987)

Resin	Million kg	% of Total
Low density polyethylene (LDPE)	1739	33.4
High density polyethylene (HDPE)	1605	30.8
Polystyrene (PS)	550	10.6
Polypropylene (PP)	480	9.2
Polyethylene terephthalate (PET)	343	6.6
Polyvinyl chloride (PVC)	265	5.1
Others	224	4.3

Source : Schell, 1989

Table 16 - Resins in plastic containers in the USA (1987)

Resin	Million kg	% of Total
HDPE	1399	53.1
PS	430	16.3
PET	336	12.8
PP	167	6.3
PVC	143	5.4
LDPE	106	4.0
Other	56	2.1

Source : Schell, 1989

APPENDIX C

APPENDIX C

The following Figures (10 and 11) will help in understanding recent non-industrial waste situation in the industrialized nations.

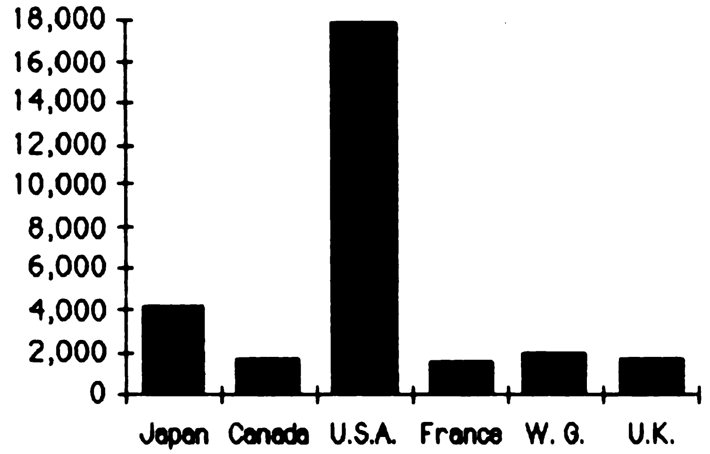

Figure 10 - Quantities of non-industrial wastes in industrialized nations
U.K. and West Germany are based on 1984 data, others on 1985 data.
Unit : 10 million metric tons per year.
Source : OECD, Environmental Data, 1989.

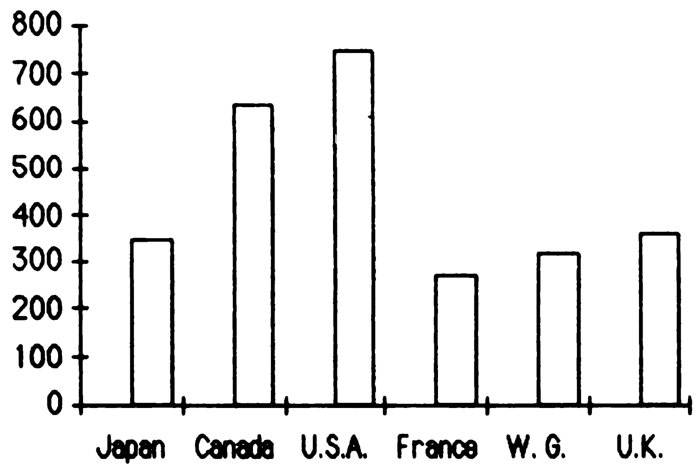

Figure 11 - Quantities of non-industrial wastes generated per capita in major industrialized nations
U.K. and West Germany are based on 1984 data, others on 1985 data.
Unit : kilograms per capita per year.
Source : OECD, Environmental Data, 1989.

APPENDIX D

APPENDIX D

The following Figure will help in understanding the decline in the number of private collectors in large cities, such as Tokyo and Osaka, in Japan.

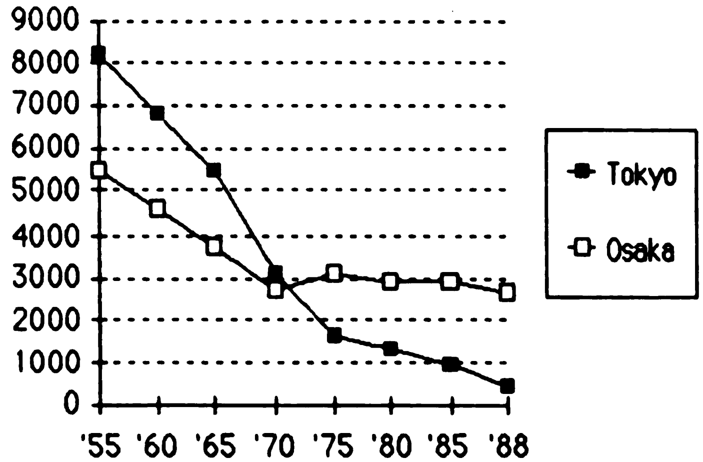

Figure 12 - Decreasing number of collectors in Tokyo and Osaka
Source : MPA, 1991

LIST OF REFERENCES

LIST OF REFERENCES

Alcoa,1987 — "Americans are recycling more aluminum cans than ever/ Alcoa Special Advertising Section," USA Today, 5 p., October 28, 1987.

Barham,1991 — Vernon F. Barham, "Recycling for the food industry," Journal of Packaging Technology, pp. 28, 29, January/February, 1991.

BIO,1990 — The staff of BioCycle, "Collection Approaches," The Biocycle guide to Collecting, Processing and Marketing Recyclables, The JG Press, Inc., Section I, 1990.

BIO,1990 — The staff of BioCycle, "Recycling Economics," The Biocycle guide to Collecting, Processing and Marketing Recyclables, The JG Press, Inc., Section II, 1990.

BIO,1990 — The staff of BioCycle, "Educating the Public," The Biocycle guide to Collecting, Processing and Marketing Recyclables, The JG Press, Inc., Section III, 1990.

BIO,1990 — The staff of BioCycle, "Planning the Program," The Biocycle guide to Collecting, Processing and Marketing Recyclables, The JG Press, Inc., Section IV, 1990.

BIO,1990 — The staff of BioCycle, "Case Studies," The Biocycle guide to Collecting, Processing and Marketing Recyclables, The JG Press, Inc., Section V, 1990.

BIO,1990 — The staff of BioCycle, "Market Development," The Biocycle guide to Collecting, Processing and Marketing Recyclables, The JG Press, Inc., Section VI, 1990.

BIO,1990 — The staff of BioCycle, "Collection Equipment," The Biocycle guide to Collecting, Processing and Marketing Recyclables, The JG Press, Inc., Section VII, 1990.

CMI,1991 — The staff of CMI, "Recovery rates for aluminum UBC in the U.S.A. (1980 - 1990)," UBC recycling situation in the U.S.A., Can Manufacturers Institute (CMI) (Japan), 6 p., 1991.

EPA,1990 — "Options to reduce the impacts of post-consumer plastics wastes," Methods to Manage and Control Plastic Wastes, United States Environmental Protection Agency (EPA), Office of Solid Waste & Office of Water, Section Five, pp. 5-24 ; 5-75, February, 1990.

FDL,1989 — The staff of NSDA, "There Are No Winners," Forced Deposit Laws, National Soft Drink Association (NSDA) (U.S.A.), pp. 3-31, 1989.

Folz & Hazlett, 1990 — David H. Folz and Joseph M. Hazlett, "A national survey of local government recycling programs," Resource Recycling, Resource Recycling, Inc., Vol. IX, No.12, pp. 82-85, December, 1990.

Henry,1989 — Paul B. Henry, "A National Bottle Bill?," Waste Age, Vol.20, No.12, pp. 118,122-124, December, 1989.

IAR,1983 — A nationwide estimate of the percentages of beer and soft drink containers in litter, Institute for Applied Research (U.S.A.), December, 1983.

JACRA,1989 — The staff of JACRA, "Contrasting quantities of beverage cans distributed in the U.S.A. and Japan in 1988," Aluminum UBC recycling situation in the U.S.A., The Japan Aluminum Can Recycling Association (JACRA), 2 p., December 5, 1989.

JACRA,1991 — The staff of JACRA, "Trend of recycling rates for aluminum UBC in Japan," Aluminum UBC recycling situation in Japan, The Japan Aluminum Can Recycling Association (JACRA), p. 12, 1991.

JCBA,1990 — "Trend of container materials used for carbonated beverages in Japan," The Annual Report 1990, Japan Carbonated Beverage Association, appendix, 1990.

JEJ,1989 — The staff of JEJ, "Save-the-earth initiative launched ; Takeshita promoting environmental diplomacy," The Japan Economic Journal (JEJ), vol.27, 3 p., April 29, 1989.

JEJ,1990a — The staff of JEJ, "Environmental action on corporate agendas ; firms that do not care about the environment will not survive," The Japan Economic Journal (JEJ), vol.28, 5 p., July 21, 1990.

JEJ,1990b — The staff of JEJ, "Consumers seek global protection but less eager to pay for clean environment," The Japan Economic Journal (JEJ), 2 p., June 23, 1990.

JEJ,1991	The staff of JEJ, "Garbage bills aim to can waste disposal crisis ; Agencies want firms to push recycling," The Japan Economic Journal (JEJ), 5 p., March 30, 1991.
JUTA,1990	The staff of JUTA, "UBC recycling efforts," Steel UBC statistical review for 1989, Japan UBC Treatment Association (JUTA), appendix, 1990.
Keller,1989	Richard Keller, "An agenda for market builders," Waste Age, Vol.20, No.12, pp. 95, 96, December, 1989.
Misner,1989	Michael Misner, "The Aluminum Can's Future Glistens," Waste Age, Vol.20, No.12, pp. 75, 76, December, 1989.
MPA,1991	The staff of MPA, "Aluminum vs. steel in the market of beverage cans in Japan," The Report of MPA Meeting, Mitsubishi Packaging Association (MPA) (Japan), appendix, July, 1991.
Nakajo,1990	Hiroshi Nakajo, "Saving energy by using recycled resources/solid waste management efforts," Nihon Keizai Shimbun (NKS), 4 p., December 24, 1990.
NKS,1990	The staff of NKS, "Plastic incineration with effective energy recovery," Nihon Keizai Shimbun (NKS) (a leading economic newspaper published in Japan), 15 p., December 23, 1990.
NKS,1991a	The staff of NKS, "Recycling, is it penetrating into societies in Japan?" Nihon Keizai Shimbun (NKS), 23 p., February 3, 1991.
NKS,1991b	The staff of NKS, "Used empty can littering has not decreased, according to Environmental Agency's research," Nihon Keizai Shimbun (NKS), 24 p., March 4, 1991.
NKS,1991c	The staff of NKS, "Action programs for promoting aluminum UBC recycling in Japan," Nihon Keizai Shimbun (NKS), 34 p., April 19, 1991.
NKS,1991d	The staff of NKS, "Mitsui group's feasibility study on PET bottle recycling business," Nihon Keizai Shimbun (NKS), 27 p., March 17, 1991.
NKS,1991e	The staff of NKS, "Cooperation of MITI and Tokyo local government in establishing recycling centers in Tokyo," Nihon Keizai Shimbun (NKS), 18 p., February 28, 1991.
NKS,1991f	The staff of NKS, "Waste management current situation," Nihon Keizai Shimbun (NKS), 30 p., June 25, 1991.

NKS,1991g — The staff of NKS, "Tokyo local government attempts to promote its recycling programs by means of renting reverse-vending machines," Nihon Keizai Shimbun (NKS), 33 p., July 30, 1991.

NYS,1988 — New York State Solid Waste Management Plan 1987-88 Update, Division of Solid Waste, New York State Department of Environmental Conservation, pp. 3-52, March, 1988.

PBCS,1991 — The staff of PACKPIA, "PET bottle current situation in terms of solid waste management in Japan," PACKPIA (Japan), Table 1, 62 p., July, 1991.

Polk,1991 — Tom Polk, "Market research for market development," Resource Recycling, Vol.X, No.2, pp. 24 -25, February, 1991.

Schell,1989 — Jeffrey M. Schell, "Plastics Recycling Rates Will Rise," Waste Age, Vol.20, No.12, pp. 195-198, December, 1989.

Selke,1988 — Susan E. Selke, "Recycling of plastic packaging in the United States," Packaging Technology and Science, Vol.193-98, 1988.

Snow,1989 — Darlene Snow, "We'll be 'recycling under crisis'," Waste Age, Vol.20, No.12, pp. 213, 214, December, 1989.

Stack,1989 — E. Gifford Stack, "A National Bottle Bill?," Waste Age, Vol.20, No.12, pp. 119-121, December, 1989.

Stuart,1990 — Matthew Stuart, "Du Pont Recycling Projects," Packaging Connection, School of Packaging, Michigan State University, 9 p., Vol.2, 1990.

Vile,1989 — Pete Vile, Waste Age's Recycling Times (The newspaper of recycling markets), Vol.1, No.16, 19 p., October 9, 1989.

Yoshino,1991 — Katsuhisa Yoshino, "Beverage container situation in Japan from an environmental viewpoint," PACKPIA (Japan), Table 2, 37 p., July, 1991.