HOW TO IMPLEMENT PLASTICS RECYCLING PROGRAM

THE COUNCIL FOR SOLID WASTE SOLUTIONS

TABLE OF CONTENTS

Printed on recycled paper

Acknowledgments

How to Implement a Plastics Recycling Program was written to provide an educational reference manual for recycling coordinators and public solid waste management officials. It is not intended to be a technical report on recycling, but rather a resource for anyone planning or implementing a plastics recycling program.

We wish to acknowledge Moore Recycling Associates, Hancock, NH, who were primarily responsible for the development of this document.

Important contributions were made by Sergio Firpo, president, Frontier Recycling Systems, Inc.; Michael Schedler, Director of Operations, Bronx 2000's R2B2 recycling subsidiary; and John Fearncombe, president, Bottom Line, Inc., and author of *Guide for Recyclers of Plastics Packaging in Illinois,* written for the Illinois Department of Energy and Natural Resources.

We wish to thank many individuals for their review of the text and for their suggestions. We are grateful to Tom Tomaszek, the president of North American Plastics Recycling Corporation, for his thorough and thoughtful review and Glenn McRae of the Association of Vermont Recyclers for his helpful contributions.

The Council for Solid Waste Solutions

The CSWS Recycling Mission

Founded in 1988, the Council for Solid Waste Solutions, a program of The Society of the Plastics Industry, Inc., is a task force of companies in the plastics industry committed to developing comprehensive, realistic programs for environmentally sound disposal and recycling of plastics.

The Council's Technical department helps move new waste management technologies from the design table to the production line. Moreover, the Council's Government Affairs and Communications departments work with local, state, and federal officials, as well as community and environmental organizations, to put these solutions in place.

Why Communities Don't Recycle Plastics

Many recycling coordinators and public works officials want to respond to citizen pressure to recycle plastics and to create plastics recycling programs. Communities are often discouraged by the following commonly perceived barriers:

"There are no markets."
"Plastics are too difficult to identify."
"Plastics are too bulky to collect."
"There's not enough room to store plastic recyclables."
"Balers are beyond our budget."
"Our trucks can't hold enough material."
"We can't afford to buy more trucks."
"In our rural area, we can't afford the transportation costs."
"Our Public Works Department's budget is stretched thin as it is, and we can't add any other programs now."

For every barrier found by a community, there exists a solution found by another municipality. The proof is that at least 500 communities currently have curbside collection of one or more types of plastic bottles and even more have drop-off centers accepting them. This guide presents *solutions.*

Please share your ideas about solutions with the Council, so they may be passed on to others.

The Council for Solid Waste Solutions
1275 K Street, N.W., Suite 400
Washington, DC 20005
1-800-2-HELP-90

About This Manual

This manual provides information about how to:

- identify different kinds of plastic materials for recycling;
- estimate the weight and volume of plastics available for collection;
- locate markets for collected plastics;
- design a program to collect plastics;
- select appropriate equipment for plastics collection;
- store, bale, and ship plastics for recycling; and
- promote your plastics recycling program.

This manual is designed to provide the most current information about plastics recycling by regularly updating and adding to the appendices.

Attached at the end of the manual is a reply card that must be returned in order to receive this updated information.

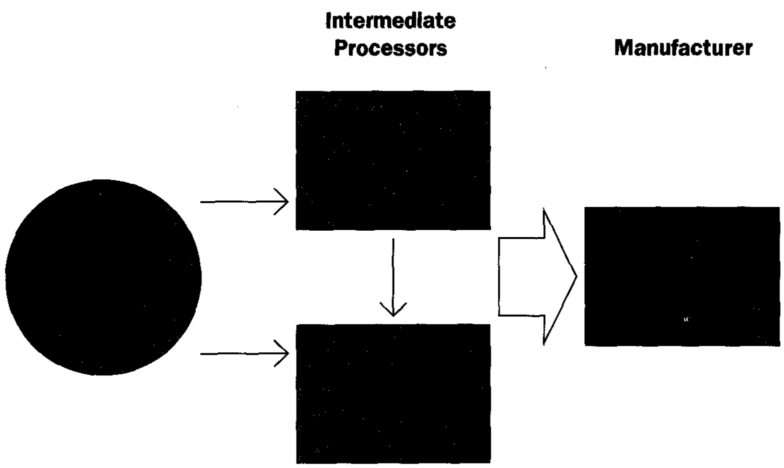
Plastics and Recycling Markets

Recycling plastics, like recycling other post-consumer materials, is a dynamic process that involves a sequence of key steps. The flow of materials creates an integrated system that begins when the manufacturer sells a product to a consumer. The consumer uses the product and then passes the material to a "market."

> For the purpose of this manual, a "market" describes a series of businesses that process plastics into acceptable forms for manufacturers of recycled plastic products. That market could be either:
>
> - a hauler—a company that transports recyclables to a handler;
> - a handler—an intermediate scrap processor that will sort, bale and/or granulate material; or
> - a reclaimer—a facility that converts the resin from bottles and containers (or flakes) into pellets ready for reuse in a new product. Sometimes the reclaimer also manufactures new products.

The basic steps in the plastics recycling process are:

1. collection;
2. separation into discrete resins;
3. reclamation (reprocessing) into flakes or pellets of consistent quality acceptable to the manufacturers;
4. use in the manufacture of products or containers; and,
5. purchase by consumers.



> The flow of materials is similar to the flow of water in a plumbing system. If the flow in the pipeline is too fast the plumbing system becomes backed up; if the flow is too slow, the trickle may not be sufficient to operate the system.

If the accumulation rate at a particular step is too slow, methods must be found either to accelerate the rate at which material is collected or provisions made to store material until appropriate quantities are accumulated.

If the rate of accumulation at a particular step is too fast for the next process in the system, methods will be needed to store the backlogged material or to accelerate the rate at which the following processes can accept the materials.

Today, as the supply of plastic recyclables increases, improved collection systems and separation technologies are needed to handle the growing demand. As consumers demand products with recycled content, manufacturers who make products using recycled resins will demand more from reprocessors. As the demand for recycled resins increases, the economic viability of plastics recycling improves.

Plastic Resin Families

This section is to help you understand why some plastic products may be acceptable to your market and why others may not. It is not intended as a collection or sorting guide for your community.

There are five major families of plastics commonly found in household packaging:

Polyethylene Terephthalate (PET)
Polyethylene (PE)
Polyvinyl Chloride (PVC)
Polypropylene (PP)
Polystyrene (PS)

There are other plastics, but these represent the majority found in household packaging. Each polymer family has unique properties that are utilized for particular packaging applications.

SPI Plastic Container Coding System

The Society of the Plastics Industry, Inc. (SPI) has developed a voluntary coding system for plastic containers that identifies bottles and other containers by material type to help recyclers sort plastic containers by resin composition. SPI codes are located on or near the bottom of bottles 16 ounces and larger and rigid containers 8 ounces and larger.

Using the input of recyclers and collectors, the plastics industry created the container coding system to provide a uniform system for coding that meets the needs of the recycling industry. The code is intended for recyclers, not residents.

Each code number represents a general resin family with many types of plastic containers with different properties. All individual products with the same resin code may not be compatible in the process used by your local reclaimer.

For example, both High Density Polyethylene (HDPE) blow-molded containers (bottles) and HDPE injection-molded containers (tubs and jars) have the #2 code. A plastics recycler may be able to handle blow-molded bottles, such as milk jugs and detergent bottles, but cannot use injection-molded containers. The reason for this is the difference in their Melt Flow Indices (MFI). The MFI measures the material's processing viscosity. Injection-molded containers have a very high MFI, while blow-molded containers have a low one.

The bottom line is to ask your market what specific products are acceptable. Do not rely on bottle and container codes alone as your guide.

Common Plastic Resin Types Found in Household Packaging

1 PETE

Polyethylene Terephthalate

Polyethylene terephthalate (PET) is the most commonly recycled household plastic material, representing about 25 percent of the plastic bottle market. PET is primarily used for soft drink bottles. It is also used for some other packaging applications for edible oils, liquor, and peanut butter.

PET has the properties of clarity, toughness, and barrier (ability to resist permeation of carbon dioxide).

In 1989, approximately 690 million pounds of PET were converted into soft drink bottles. Nationally, this averages to about one two-liter bottle per household per week. (About seven two-liter bottles equals one pound.)

[illegible]

Carpet
Fiberfill
Strapping
Non-food Bottles and Containers
Geotextiles
Surfboards
Sailboat Hulls
Industrial Paints

The recycling rate of PET plastic soft drink bottles reached an all-time high of 28 percent in 1989, according to the National Association for Plastic Container Recovery (NAPCOR). Overall, 190 million pounds of PET plastic containers were recycled, representing a nine percent increase over the 1988 recycling rate.

2 HDPE

4 LDPE

Polyethylene

Polyethylene is the most widely used plastic in the household. It is a family name which includes specific plastics such as Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE).

LDPE is widely used in applications requiring clarity, inertness, processing ease, and moisture barrier. Its largest end use is film for bags, such as bread bags or trash bags.

HDPE is characterized by its stiffness, low cost, ease of forming, and resistance to breakage. HDPE has a variety of uses such as milk, water and juice beverage bottles; bleach and detergent bottles; motor oil bottles; margarine tubs; and grocery sacks. It represents over 50 percent of the plastic bottle market. In 1987, 2.2 billion pounds of household bottles made from HDPE were sold.

[illegible]

Detergent Bottles
Trash Cans
Soda Bottle Base Cups
Drainage Pipes
Animal Pens
Drums/Pails
Matting
Milk Bottle Carriers
Pallets

Approximately 800 million pounds of milk jugs are thrown away each year, which represent a significant resource for recyclers. In 1989, about 145 million pounds of HDPE were recycled. Milk jugs that are separated from colored HDPE bottles such as motor oil, bleach, fabric softener or detergent containers are valuable to markets. They currently command a greater price on the market because they can be remanufactured into a greater variety of end products.

Colored HDPE containers are being recycled into products such as motor oil bottles, irrigation and drain pipes, and pails.

Polyvinyl Chloride

3 V

Because of its blending capability, polyvinyl chloride, also called PVC or vinyl, can be used to manufacture products ranging from heavy-walled pressure pipes to crystal-clear food packaging, most often, bottles for cooking oils, water, household chemicals, and health and beauty aids. Properties of vinyl include good clarity and chemical resistance.

Vinyl bottles make up less than six percent of plastic bottles typically found in the household.

About five million pounds of vinyl were collected for recycling in 1989 alone.

In September 1989, Occidental Chemical Corporation announced a nationwide commercial program to buy back vinyl bottles. Baled bottles are purchased in lots of more than 5,000 pounds at prices equal to comparable grades of PET bottles. A system for separation of vinyl from PET and other resins has been developed by National Recovery Technologies of Nashville, Tennessee, and the Center for Plastics Recycling Research at Rutgers, The State University of New Jersey.

[illegible]

Drainage Pipe
Fencing
Handrails
House Siding
Sewer/Drains

Polypropylene

5 PP

Polypropylene (PP) is resistant to chemicals and fatigue and has a low specific gravity. It has gained wide acceptance in applications ranging from fibers and films to food packaging such as screw-on caps and lids, some yogurt and margarine tubs, syrup bottles and straws.

For the last 30 years, polypropylene has been used as the primary material for automotive batteries because it is lightweight, durable, and recyclable.

According to HIMONT U.S.A., Inc., 150 million pounds of polypropylene from used automotive batteries are recycled each year in the United States, accounting for 95-98 percent of all dead batteries. About 40 percent of the recovered polypropylene is used in the next generation of batteries. The balance is used for other automotive applications and in consumer products including wheels for barbecue grills and lawn mowers.

[illegible]

Auto Parts
Batteries
Bird Feeders
Furniture
Pails
Water Meter Boxes
Bag Dispensers
Golf Equipment
Carpets
Refuse/Recycling Containers
Geotextiles
Industrial Fibers

Polystyrene

6 PS

Polystyrene (PS) is a versatile resin with a range of physical properties that include clarity, ability to foam, and relative ease of processing. While it is one of the least used plastics for household packaging, it is used in some yogurt cups, egg cartons, meat trays, disposable drinking cups, plates, cutlery, and foam cups.

A growing amount of polystyrene is now being recycled—20 million pounds were collected last year. Initial efforts to recycle PS in hospitals and quick-service restaurants are proving successful. PS collection programs are under way at school cafeterias and businesses. Neighborhood drop-off sites for household polystyrene are becoming more common and curbside collection is being tested.

The National Polystyrene Recycling Company (NPRC) was formed by the nation's largest manufacturers of polystyrene resins to establish a nationwide polystyrene recycling infrastructure. The NPRC to date has invested $16 million to facilitate the recycling of 250 million pounds of polystyrene per year by 1995. That represents 25 percent of the polystyrene produced annually in the United States for food service and packaging.

Insulation Board
Office Equipment
Office Accessories
Household Products
License Plate Frames
Reusable Cafeteria Trays

NPRC is developing several regional polystyrene reprocessing facilities in the major metropolitan areas of Boston, Chicago, Los Angeles, New York, San Francisco, and Philadelphia.

Other Plastics and Commingled Plastics

7 OTHER

Most sorting of plastic bottles and containers today is done by hand. While a number of automatic sorting technologies currently are under development, manual sorting is likely to continue in the short term. However, even after the most valuable resins have been removed from the sorting stream, the various plastic bottles and containers that remain still can be recycled. They can be remanufactured, by a technology known as commingled or mixed plastics recycling, into a variety of product applications.

Landscape Timber
Pens for Farm Animals
Roadside Posts
Pallets
Marine Pilings
Benches
Picnic Tables

About 30 million pounds of the mixed or commingled plastics were recycled in 1989.

Recycling and End-Use Markets

Resins can be separated and reclaimed for many end uses. High-quality single resins command the largest and most profitable markets for recycled resins, although commingled recycling technology is available in some areas of the country. In either case, manufacturers of consumer products require consistent purity to maintain the same product performance that they can get from virgin material.

The regulations of the Food and Drug Administration (FDA) allow the use of recycled plastic resins (as well as recycled materials other than plastics) as long as they comply with the regulations for the generic type of material and are pure enough for use in food packaging. Companies in the plastics industry have developed technology for including recycled plastics in food packaging and they are keeping the FDA informed of developments in this area.

Products From Recycled Plastics

One useful source of information on products made from recycled plastics is the *Recycled Products Guide*, published three times a year by American Recycling Market, P.O. Box 577, Ogdensburg, NY 13669.

Survey All Available Markets

Locate a Market by Calling the Council for Solid Waste Solutions

For help in locating markets for recycled plastics anywhere in the United States, call the Council for Solid Waste Solutions toll-free at 1-800-2-HELP-90. The Council maintains a database of more than 700 companies that buy plastics from communities. Our operators can search for markets by geographical location and by resin type handled.

Another source is the *1991 Directory of U.S. and Canadian Scrap Plastics Processors and Buyers,* which is available by writing Resource Recycling, Inc., P.O. Box 10540, Portland, OR 97210 or calling 1-800-227-1424. The cost is $40.

For additional information, subscribe to or borrow from the library one of the trade publications listed at the end of this manual.

Conduct a Market Survey

Before selecting a market, take a survey of all potential handlers. This is the best way to match the community's plastics variety and collection rate with the most economical and efficient market.

To determine the specifics of each market, ask the following questions:

What kinds of plastics will each market accept?
Plastic market categories usually include:

Category	Resin Recovered
Soft Drink Bottles	PET (and colored HDPE from base cups)
Milk, Juice and Water Jugs	natural HDPE
Beverage Bottles	PET, natural HDPE, clear PVC (and colored HDPE from base cups)
Detergent/Bleach Bottles	colored HDPE
All Bottles	PET, colored and natural HDPE, PVC and some LDPE, PP and multilayer
All Rigid Containers	PET, HDPE, PS, PVC, PP, LDPE and multilayer
All Clean Plastics	PET, HDPE, LDPE, PS, PVC, PP and multilayer

What are the market's processing requirements?

How does the market want to receive material?
Who will separate the materials?
Does the market want the material loose, baled, compacted or bagged?

Keep in mind that the more separation and processing done before shipping, the higher the value and the sale price received for the plastic.

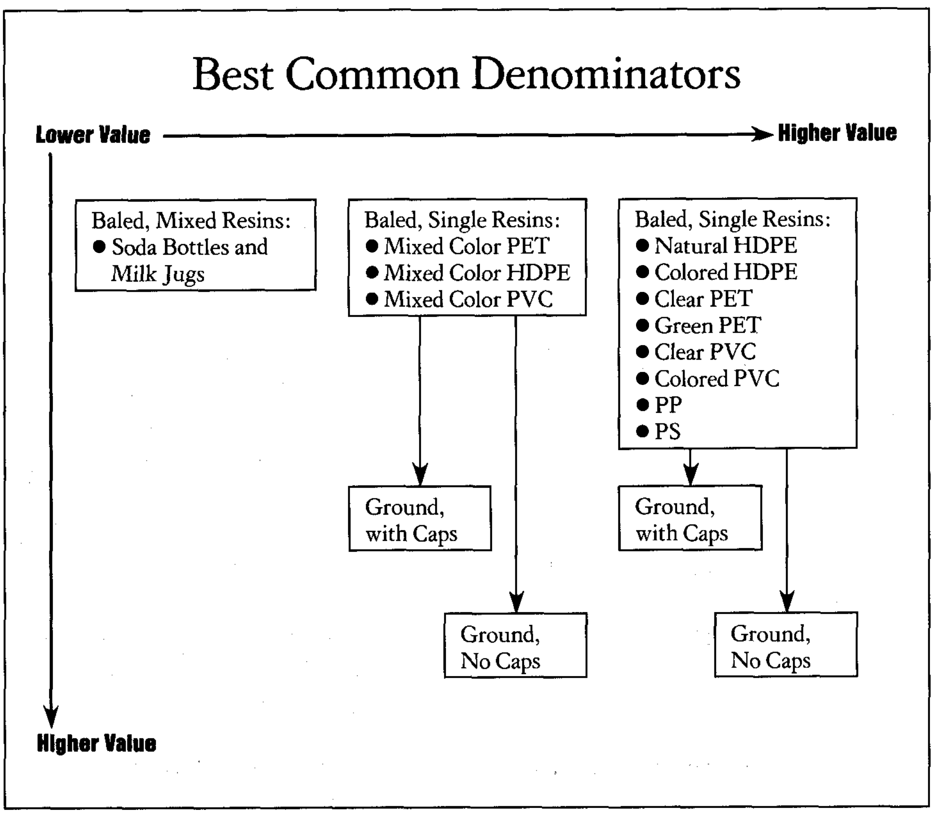
NOTE: We do not recommend that municipalities granulate their plastics because of the risk of material contamination. A very small amount of PVC in a PET shipment can render the entire PET shipment unacceptable. The risk of contamination may be less of a problem in the future as more advanced separation technology develops.

What contamination restrictions apply?

Determine what materials are considered contaminants. Be specific about what plastics can and cannot be accepted.

Can caps and rings be left on?
How about labels?
What percentage of unacceptable plastic resins are allowed?
What materials are unacceptable even in small quantities?

The following chart* explains how to increase the value of recycled plastic. The chart starts in the upper left corner with material of the lowest value that is marketable nationwide.** Each step taken either down the page or to the right will increase the value of the material.



* This chart is reprinted with permission from Michael Schedler, Director of Operations,

Who will be responsible for the transportation of the material?

Determine the shipping arrangements.

Will the market pick up the material or does it have to be delivered?

Are minimum quantities of material required? Some markets require truckload quantities of at least 30,000 pounds.

Will the market provide any other services?

Some markets will provide equipment leases, promotional materials and/or technical assistance with the implementation of the program.

How much will the market pay for the material?

Each of the variables described above will affect the value of the material. Clean, resin-separated, high-volume and compacted materials will bring a better price than loose, mixed, small amounts of plastic.

Estimate the Quantity of Plastic Recyclables for Collection

Worksheet: Estimated Recovery Levels

A. How to Calculate Estimated Weight:

- Look at the Estimated Recovery Levels chart at the bottom of this page. Find the RECOVERY LEVEL (lbs./household/year) of the collected resins. Write that number below.

- __________ x __________ = __________
  RECOVERY LEVEL (lbs./household/yr.) — # of households to be served by program — Estimated lbs./yr.

- __________ ÷ 52* = __________
  lbs./yr. — Estimated lbs./ collection week

B. How to Calculate Estimated Volume:

- From the Estimated Recovery Levels Chart find the Bulk DENSITY for the resins to be collected.

- __________ ÷ __________ = __________
  Estimated lbs./ collection week — DENSITY (lbs./cu. yd.) — Estimated vol./ collection week

- __________ ÷ __________ = __________
  Vol./collection week — # of truckloads/week — Volume/truck

Estimated Recovery Levels of Plastic Resins in a Curbside Program

Category	Resins Collected	Estimated Recovery Level pounds/ household/ year	Estimated Density pounds/cubic yard with Step-On-It Program
Soda Bottles	PET	5-11	30-45
Milk Jugs	natural HDPE	5-10	25-30
Soda Bottles and Milk Jugs	PET, natural HDPE	8-17	30-40
Beverage Bottles	PET, natural HDPE, clear PVC	8-18	30-40
Detergent and Bleach Bottles	colored HDPE	1-2	35-50
All Clean Bottles	PET, natural HDPE, colored HDPE, colored PVC, PP, multilayer	15-24	40-50
All Rigid Containers	PET, HDPE, PS, PVC, PP, multilayer	20-30	45-55
All Clean Plastics	PET, HDPE, LDPE, PS, PVC, PP, multilayer	25-40	NA

How much plastic can be anticipated?

The following list of conditions will help estimate how much plastic may be recovered.

Situation:	Effect:
Very high participation	Increase all recovery numbers
Very low participation	Decrease all recovery numbers
Drop-off instead of a curbside program	Decrease all recovery numbers substantially
Beverage bottle deposit state	Decrease to close to zero the amount of PET bottles recovered
Poor drinking water quality	Increase the amount of natural HDPE, clear PET and PVC bottles
Sales mix of beverage containers (glass, plastic, aluminum)	A waste composition study will help determine local effects
Consumption level of beverages either generally or seasonally	A waste composition study will help determine local effects

Studies show that when plastics are included in a recycling program, higher volumes of all *recyclable materials are recovered.*

Negotiate a Contract with a Market

Long-Term Versus Short-Term Contracts:

Consider the pros and cons of negotiating a long-term contract or playing the spot market. The trade-off is between the security of a guaranteed price and the potential opportunity to earn a higher return.

A long-term contract has the advantage of providing a buyer at a set price. If the market should weaken, the handler will still pay the set price. The disadvantage of such a contract is that if demand for plastics increases, the rate increase will not be reflected in the price paid for plastics.

With large quantities of plastics, consider contracts with more than one market. This will ensure a measure of security. If, for an unforeseen reason, one market changes the specifications for the material it will accept, or is unable to handle your material, other contracted handlers may be able to manage it. The disadvantage to writing more than one contract is that smaller quantities will be allotted for each handler and may command a lower price.

Additional Questions to Ask When Selecting a Market and Negotiating a Contract:

1. Conditions of the material

Generally, municipalities get better prices if their plastic is compacted or baled. Compacting or densifying plastics before transporting is a cost-effective method of lowering expensive hauling costs. (Refer to Appendix B about selecting an appropriate baler.)

In what form does the market want the material for transportation?

- Baled?
- Compacted?
- Shredded?
- Granulated?
- Loose?
- How much dirt and contamination are acceptable?
- Does the market require a minimum weight or volume before it will accept delivery?
- Will the market come to pick up the material on a regular basis? In an emergency?
- What will constitute a rejected load?

2. Containers

- Will the market provide containers in which to collect, store, or transport the material?
- If so, is there a charge or rental fee for the containers?
- Will the market accept containers provided by the municipality or business?

3. Transportation and scheduling

Weighing:

- Where will the material be weighed?
- How and when will copies of the weight slips be available?
- Consider weighing the material before it is transported. This will eliminate the burden of lost weight slips and confirm the accuracy of weight slips from the market.

Delivery "Bonus":

- What is the price differential between a delivered load and a picked-up load?
- Is there a "bonus" for delivered loads?

Contamination:

Have a standard procedure for dealing with rejected loads of material. It is important to establish the possibility of contamination and the ensuing costs in the contract.

- If a load is rejected by the market for any reason, what should the transporter do with it?
- Return it?
- Dispose of it in another way? How?
- What additional costs are incurred?

An alternative may be to reprocess the plastic and resell it or pass it to a market that will accept the contaminated material for little or no money. Either way may be less expensive than landfilling the material.

4. Scheduling issues and fee structure

- If the market is providing transportation, will the hauler be on call to come for a pickup when a certain weight or volume is collected?
- How much lead time does the market require before a hauler picks up material?

Consider establishing a penalty for not picking up the material on time.

Pricing:

Consider including a clause that allows changes to the terms of the contract if there are substantive changes in the contract assumptions (such as if the program changes and much larger material quantities are collected or if market prices change radically). The contractor may want some flexibility as well. Keep in mind that the greater the flexibility, the higher the price the market will pay for the decreased risk.

- Can the fee structure be changed during the contract or only at the end of the contract?
- If the former, under what circumstances?

Base Price:

A contract that provides a base price for the material and adjusts to market fluctuations will decrease risk exposure.

Length of Contract:

Shorter contracts provide greater flexibility to take advantage of rising prices; longer contracts provide more security in an unsteady market environment. Processors favor long-term contracts for a steady supply of material.

Payment:

- When will payment be received? After delivery of each load? Monthly? Net 10? Net 30?
- Will interest charges be paid to you for late payments?

5. References

Be sure to obtain and thoroughly check the buyer's references with existing contract holders.

- Does the market perform according to the contract specifications?
- Does the market pick up material reliably? On schedule?
- Does the market keep to the agreed fee schedule?
- Is payment prompt?
- Has material to this market been rejected often or unfairly?
- Are the weights accurate?

6. Haulers

If transportation services are not provided by the market and if it is not practical to use municipal vehicles, locate a hauler for the transportation of the plastics to the market. Look in the *Yellow Pages* or call your local waste hauler for further information.

Design a Plastics Collection Program

Once you know what materials and volumes you will be collecting, have chosen a market, and know that market's requirements, you are ready to design a collection program that is tailored to these conditions.

Include Plastics From the Start . . .

The best approach is to *include plastics in the design of your recycling program from the start.* By so doing you will be assured that your collection and storage volumes are properly sized. The recycling collection program should mimic, as closely as possible, the solid waste collection system (for example: if an area has curbside collection of trash it should also have curbside collection of recyclables).

. . . But if You Can't

If there is a program already in place and you are adding plastics to it, consider these principles:

1. Integrate plastics into existing programs.

The key to a cost-effective program is to integrate plastics into the existing infrastructure of the recycling program. It is not cost-effective to have a separate collection and handling system for plastics only. This would mean that you have to support both systems. *Integration is the key.*

2. Plastic recycling programs should mimic existing programs.

If the existing recycling program collects cans and bottles commingled, ideally plastics should be mixed in with them. If collection is weekly, curbside, and source separated, then the plastics should be added weekly, curbside, and source separated and collected with the same vehicle or a slightly modified collection system.[1]

3. Target the plastics for which you have located markets.

Plan to start by collecting the *maximum* amount of material based on what your market will accept. High-volume containers such as soft drink bottles; milk, water and juice jugs; and colored HDPE bottles are most likely to find ready markets. Other resins that are determined marketable by future market surveys can be added after the program is well established and as new markets become available.

The following are likely to maximize the recovery of plastics:

- multi-material curbside collection;
- mandatory separation requirements;
- use of household set-out containers;
- weekly collection frequency;
- the widest possible range of plastics (and other materials) included in the program; and
- effective promotion, with clear specification of the types of plastic products to be included *and* not included.

The following characteristics will increase the cost efficiency of plastics collection:

- commingled collection of loose container materials;
- use of large collection vehicles; and
- one-person collection crew size.

Plastics collection viability may also be enhanced by the following measures:

- collection of recyclables on the same day as refuse collection;
- use of [illegible] loading truck types;
- [illegible]
- [illegible]
- [illegible]

Curbside vs. Drop-off: What's Right for Your Community?

The ideal recycling program in any given area is the one that will work within the constraints imposed by the community and will get the job done at the lowest overall cost.

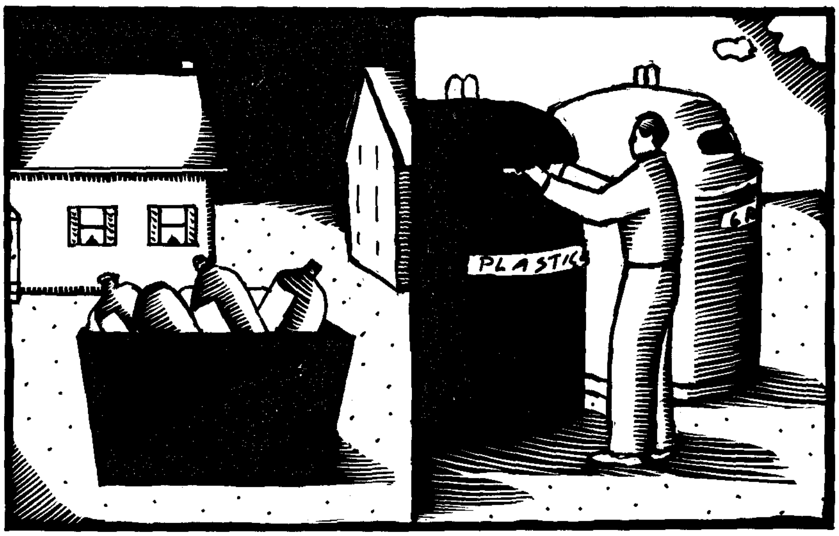
The question of how to most effectively collect plastics can only be answered on a case-by-case, program-specific basis.

Determining the most effective collection programs requires some degree of trade-off between maximizing materials recovery rates and minimizing collection costs.

Strictly in terms of cost-effectiveness, the ideal situation incorporates a mandatory recycling law to maximize recovery levels combined with a monthly collection schedule. But the many factors affecting the design of a community's recycling program make this impossible for all communities.

In deciding between curbside or drop-off collection of recyclables, consider your objectives as well as the services available.

Curbside collection is the most effective and convenient program, which is why it has become an increasingly popular trend in the United States. The convenience of curbside collection has shown a significantly higher recovery rate of quality recyclables when compared to drop-off programs.



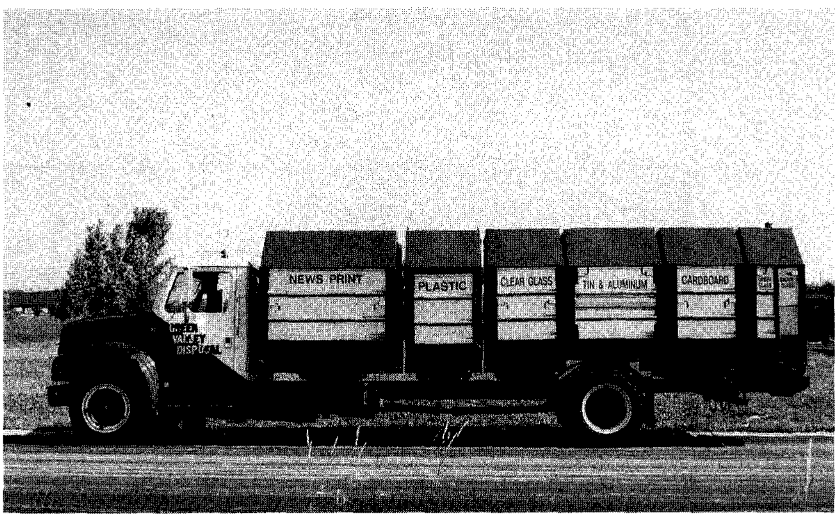
What Are the Components of Curbside Collection?

There are many ways to design a curbside collection program. Each program component has advantages and disadvantages. Consider the following program components.

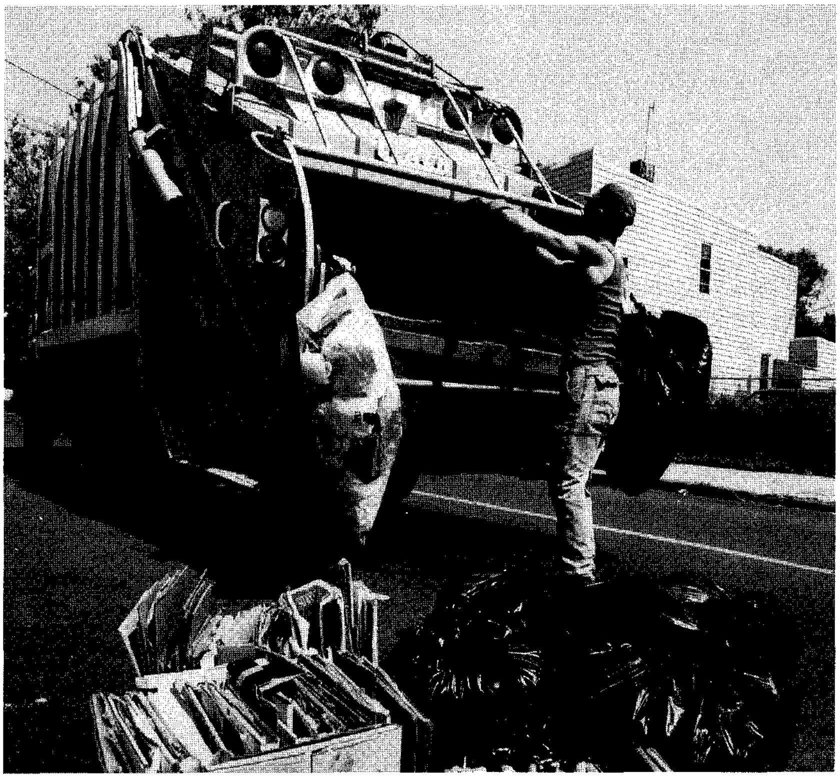
1. Commingled or separated

Collecting commingled materials has the advantage of being an efficient and relatively easy method. The disadvantage is that a subsequent facility for sorting is required. All materials need to be sorted and processed before transporting them to the market. If commingling is not feasible, separation of the materials can be done either by the residents or at curbside by the vehicle driver.

The advantage in having residents separate their recyclables is the savings in labor costs. The disadvantage is that the capture rate may decline substantially as the public is required to do more separation. Many homeowners feel that separating out many different categories of materials is inconvenient. Separation by the driver at the truck will be more convenient for the public, but will increase collection labor costs.



This recycling vehicle features right-hand stand-up drive, dual side loading, and 27.3 cubic yard usable capacity. Specially designed with compartments for plastic (including a compactor), clear, green, and brown glass, tin, and aluminum, materials are separated at the curbside by the driver or crew. Newsprint and cardboard are tied and bundled separately. The compactor has room for 3,000 milk jugs or 500 lbs. of plastic. On average, this vehicle can service 80 homes an hour with separation done by driver. (Photo of International Harvester Low Profile courtesy of Green Valley Disposal, Monroe, WI.)



Commonly used in rubbish removal, a packer truck can be used to collect recyclables, too. This truck with a two-person crew can pick up commingled materials to be separated at a processing facility. Newspapers are bundled and collected separately. (Photo courtesy of Steve Elmore, Jersey City, NJ.)

Most curbside collection operations benefit from increased commingling of recyclables in the collection vehicle, since sorting time required at the truck during each stop is reduced.

Commingling also reduces the need to deal with the problem of differential "cubing out" of compartments on the vehicle (having one compartment fill faster than others), although some trucks are available with variably sized compartments.

Although commingling generally benefits collection, it complicates the processing operation and may have an impact on both the quantity and quality of the final products marketed. Some degree of separation of the component materials must occur at a Material Recovery Facility (MRF) or handling facility before the individual materials are further processed to meet the requirements of the selected markets.

Cross-contamination of commingled material (e.g., shards of glass in aluminum cans) may occur and affect the quality of materials produced at the MRF. The commingling options can, and should be, assessed based on the net system benefits of both collection and processing.

2. Same day as regular trash pickup or a different day

The advantage to collecting recyclables on the same day as regular trash collection is that it makes it easy for residents to remember. The disadvantage is that collection routes may have to be adjusted in order to have sufficient vehicle capacity. Once a schedule is set, allow a few weeks for residents to adapt to the schedule.

3. One driver/operator or multi-person crews

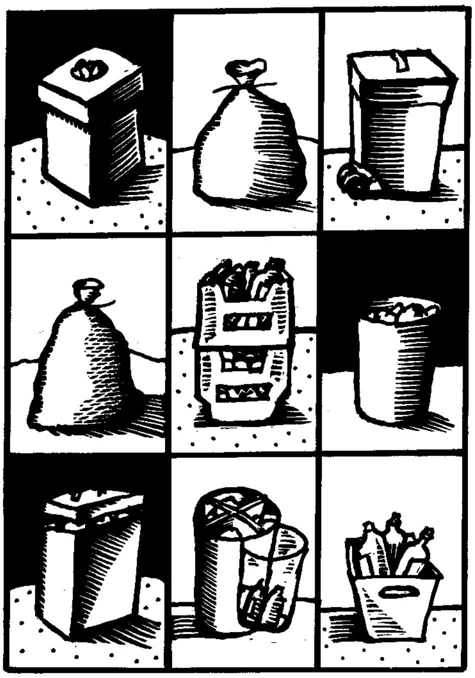
A program designed to operate with one person per vehicle will be most cost effective. Labor is the highest cost in most recycling programs. In most cases, a second or third crew member will add

4. Household recycling containers

Many curbside recycling programs provide residents with a household collection container to facilitate participation and collection. The number of containers varies from one to three; the types include plastic bins, bags and large roll-out carts.

Evidence from numerous studies shows that programs significantly increase participation rates and hence recovery levels when collection containers are provided.

Using uniform recycling containers has the added advantage of creating peer pressure among residents. When neighbors have their "blue boxes" out on collection day, peer pressure to "get with the program" is created for those who are not yet participating.



Providing uniform recycling containers, either bins or bags, is an optional program cost. However, it makes collection easier for the driver because recyclables are easily identified. If random recycling containers are used, drivers may spend extra time trying to determine which are recyclables and which are not.

Use of bins rather than bags means increased start-up costs. However, bins are only a one-time program expense, whereas bags may need to be replaced.

Some communities encourage reuse of plastic grocery bags to hold recyclables. An advantage of bags is the labor saved in collection because the driver does not have to return the container to the curb. However, the bag system requires that the bags be broken open, emptied, and gathered for either recycling or disposal.

A list of manufacturers of household recycling containers made with recycled content is included as Appendix D of this manual.

A rectangular plastic bin or box is generally favored over the other container options for the following reasons:

- a box is easier to pick up and unload recyclables into the truck;
- a box can be hooked to the side of the collection vehicle for curbside sorting;
- [illegible] compared

5. Efficient collection vehicles

An efficient collection vehicle allows collection at the greatest number of stops per day within the particular constraints imposed by a community's topography and road systems.

As a rule, curbside collection vehicles with movable interior partitions are better able to add plastics to the recycling program, and are more flexible than open bin vehicles with fixed compartment sizes.

The original purchase price may appear to be the largest contributor to overall costs. However, labor costs typically far outweigh the amortized purchase price of the collection vehicle. For more information on selecting a truck, see below.

Which Trucks Are Best Suited for Recyclables?

In looking for a new collection vehicle, program planners should look for trucks that can be economically operated and maintained and yield the highest productivity (homes served or pounds collected per hour) possible. Although the number, type, and condition of other recyclables collected at the same time as plastics will dictate the best vehicle design to a large extent, the following factors should also be considered.

1. Purchase price

Purchase price is not always the largest contributing factor of overall costs. Again, labor costs far outweigh the amortized purchase price. For example, the amortized capital cost of a $70,000 state-of-the-art collection vehicle requiring a one-person crew will be approximately $12,000 annually including interest, assuming a seven-year life. A small pickup or one-ton truck pulling a trailer might only cost $35,000 to purchase or $6,000 a year over a seven-year period. However, the required two-person labor costs will be $40,000 to $50,000 annually, compared to $20,000 to $25,000 for one person on the "more expensive vehicle." The combined annualized labor and purchase costs of $32,000-$37,000 for the state-of-the-art equipment is substantially less than the $46,000-$56,000 for the more labor-intensive system.

2. Cost-effective equipment operation and maintenance features

The following features contribute to cost-effective equipment operation and maintenance.

Size

In most cases, the truck should have a capacity of at least 28 cubic yards.

Diesel Engine

Diesel engines typically are twice as fuel efficient as gasoline. Currently diesel fuel and gasoline are comparably priced.

Automatic transmission

The constant need to stop-and-go makes use of manual transmissions too time-consuming and too expensive to maintain.

Minimal hydraulics

Hydraulically assisted loading requires additional hydraulic cylinders, electric hydraulic activating systems, and moving parts that require added maintenance and ultimate replacement.

Air brakes

Hydraulic or vacuum-assisted brakes cannot withstand the heat generated from repetitive starting and stopping at short intervals.

3. Operational features that maximize labor productivity

Right- and left-hand stand-up drive

This allows a one-person crew and makes collection possible from both sides of the street by making access and exit from the driving position easy.

Easy cab access and exit are best accomplished with cabs factory-designed for the application, i.e., high-frequency pickup. Retrofitting conventional cabs does not accomplish this goal.

Dual-side loading (ability to be loaded from both sides)

Reduces route miles and collection time.

Low loading height for the whole load

This is accomplished through use of front-wheel drive (eliminates need for a drive shaft under body of truck) or hydraulically operated loading hoppers that dump "over the top."

Large usable carrying capacity

Vehicles with less than 28 cubic yards capacity often will run out of space, requiring excessive off-route time for unloading.

Movable body partitions

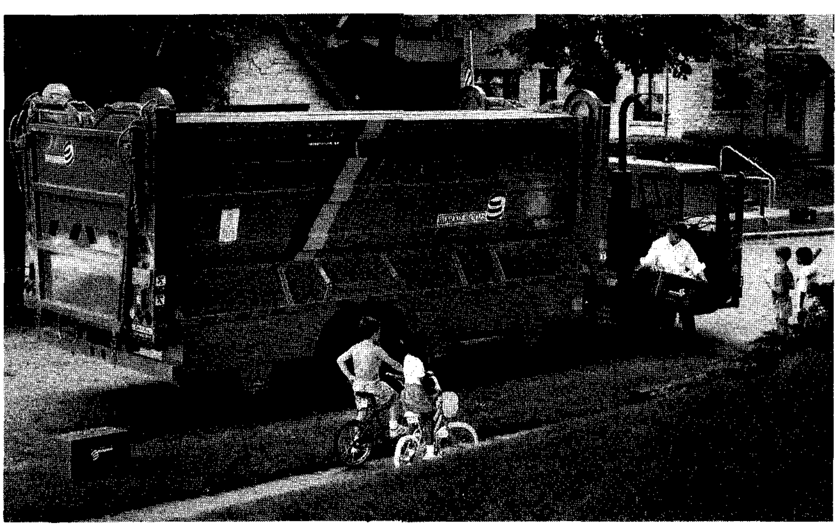
Necessary to allow for inevitable fluctuation in ratio of volumes of various recyclables collected.

Volume reduction

Compaction of plastics, metal cans, or corrugated cardboard to increase the number of stops serviced per load.

Accessibility of shifting and parking brake levers

Best when centrally located to minimize application and release time.



A side loading or "over-the-top" recycling vehicle minimizes loading fatigue for the crew. (Photo courtesy of Dempster, Toccoa, GA.)

How Can Existing Collection Programs Be Modified to Accommodate Plastics?

Not every community has the luxury of starting its recycling program with all new equipment. But plastics can be effectively added to existing programs, too.

When adding plastics to an existing recycling program, the collection may need to be modified by some combination of the following:

1. reducing the volume of the plastics through compaction,
2. adding capacity (cubic yards) to the collection vehicles, or
3. modifying collection routes.

Reducing the volume of plastics

1. **Educate the public to squash the plastic bottles.**
   Let the public know that by flattening bottles before setting them out they are helping to increase the density of the plastics and decrease the cost of the collection program. Also, crushed plastics will occupy less space at home. Recommend that they remove the cap and then carefully squeeze or step on bottles.

2. **Use a compactor retrofitted to one compartment of a dedicated recycling vehicle or purchase a truck with a compactor.**
   Check with the processing facility to assure that it can receive and sort compacted containers.
   If an on-vehicle compactor is selected, the compactor design should match the collection truck and collection route requirements.

This on-board compactor holds about 20 one-gallon jugs in the hopper chamber and compacts approximately 12 to 15 cubic yards of HDPE and 13 to 16 cubic yards of PET plastic. The Plastic Pac compactor can be mounted on a Lodal ECO 3000 recycling truck. (Photo of Inger-Teco Plastic Pac Compactor, model LC-100A, courtesy of Ms. Hillary Horner, Recycling Coordinator, City of Titusville, FL.)

If the truck is dual-side loading, the compactor should be a dual-side design.

The compactor's cycle time should match the route requirements. If the average stop-time is 15 seconds but the compactor cycle time is 20 or more seconds, there may be delays in the route that could be avoided by using a compactor with a shorter cycle time.

To gain from the use of on-board compaction, there must be a compensating improvement in collection efficiency, such as an increase in the total number of stops that can be serviced per truck.

In order for an on-board compactor to improve the collection efficiency for plastics, this equipment must:

- have a loading hopper with sufficient capacity to handle a peak amount of plastics from a household set-out;
- allow for compaction "on the run" in order to minimize the collection time per stop; and
- achieve volume reduction ratios on the order of 9:1.

3. **Packer trucks can collect commingled recyclables.** During collection, the push-out plate is moved to the front of the truck. Pressure from the "sweep" blade of the truck will apply "mild" pressure to the commingled mix to compact the plastics and other recyclables slightly and provide the added advantage of cushioning the glass containers to minimize breakage.

4. **An over-the-top collection vehicle can be modified.** Add a "packer wedge" at the top of the vehicle. Because plastic recyclables are lightweight, they will "float" to the top of the load. A wedge will add pressure on the top of the load and compact the plastics.[1]

[1] A study conducted by the Rhode Island DEP showed mixed results because the wedge itself took up

5. **A pickup-sized packer truck can be used to collect the plastics.**
   A pickup-sized packer truck could be used in conjunction with a trailer for other recyclables. The advantage of this method is lower costs if a truck and trailer system is already available. The disadvantages to this method are higher labor and safety concerns associated with using articulated vehicles.

Adding capacity to the collection vehicles

Plastics are lightweight and will "float" to the top of commingled loads. They can be added to the back or side of a recycling truck without shifting the weight of the truck.

Some examples of how to add capacity for plastics collection include:

- add a "cage" on top or on the back of the collection vehicle or trailer;
- use netting or a bag (such as the nets used to store basketballs) on the side or back of the collection vehicle to hold the plastics; or
- put the plastics in an unused part of the collection vehicles (e.g., if using a truck and trailer operation, use the truck bed for plastics or use the trailer hitch area).

(Left) A simple solution is adding a trailer to the back of a recycling vehicle. Because the trailer was added, the vehicle can haul larger amounts of plastic soda bottles and milk, juice, and water jugs. (Photo courtesy of Dan Krivit and Associates, St. Paul, MN.)

(Right) By hooking large netted bags to the back of a recycling vehicle, limited plastics capacity is added to an existing recycling program. This method is largely used as a stop-gap measure before plastics recycling fully develops because the bags tend to fill more quickly than other compartments and then need to be off-loaded for ultimate collection by another truck. (Photo courtesy of Dan Krivit and Associates, St. Paul, MN.)

Modifying the collection routes

Another way to accommodate the additional volume that will result from increased recovery of other recyclables and added plastics is to shorten collection routes.

Rural Curbside Collection or Drop-off Location Programs

Curbside collection programs are the most efficient in many areas. However, in some settings, especially in rural areas, drop-off recycling programs are better suited for the community.

Follow the suggestions for locating a market and designing a market survey. See pages 19 to 21.

To calculate the quantities of materials to be collected, use the Estimated Recovery Levels chart and worksheet (page 23).

Drop-off programs normally recover significantly lower quantities than curbside programs, so numbers need to be adjusted accordingly.

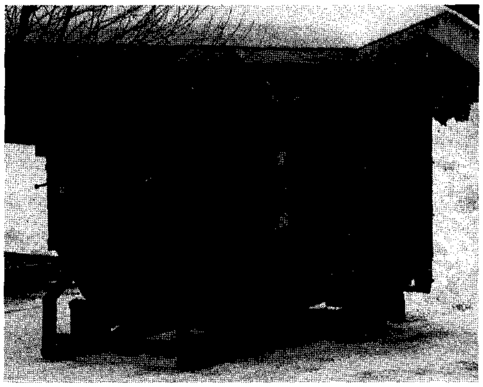
Special Considerations for Rural Areas:

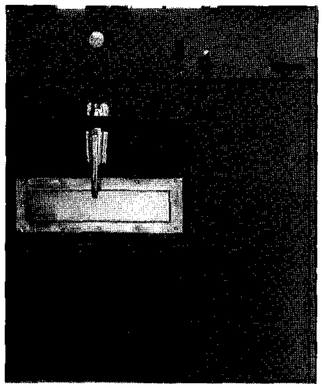
1. Quantity

Some markets in rural areas require a truckload quantity (30,000 to 40,000 pounds) before they will pick up or accept delivery. If this is the case and if it will take some time to collect the required quantity, plastics recycling is still possible and worthwhile. All programs, no matter how small the population, can include plastics as long as there is a place to store the plastics until a full load has been collected.

2. Storage

Appropriately sized containers will be needed to collect the plastic recyclables. Containers with at least 15 cubic yards capacity will accommodate the accumulation rate of most rural programs where residents crush or step on the bottles. Larger bins will be needed if the bottles are collected uncrushed. Fifteen cubic yards of material is also the minimum amount of feedstock required to make a 600- to 800-pound bale of PET and HDPE bottles. For more information on balers see Appendix B.





(Left) A small roll-off mounted compactor can be used to store recyclables in rural settings to reduce collection and transportation costs. (Photo courtesy of Dale Heikkinen of Multitek, Prentice, WI.)

(Right) This compactor can compact large quantities of plastic, glass, and cardboard. It may be operated at a recycling site or mounted on a recycling vehicle for mobile compaction. It can be powered by gas or electricity. (Photo of Stack Pak Machine courtesy of Source Recycling System, Wheat Ridge, CO.)

3. Location

Plan a storage location where the plastic recyclables will not degrade due to exposure to ultraviolet rays from the sun and where they will not become contaminated with soil and other debris. The storage can be outdoors; moisture will not hurt rigid plastics. A black tarp will provide sufficient protection from sunlight.

4. Compaction

Collected plastics can be more efficiently stored if they are compacted or baled. Material compacted in a roll-off compactor or a packer truck can be cost-effectively shipped up to a distance of about 50 miles. For distances greater than 50 miles, materials should be baled.

5. Marketing collaboration

Consider working cooperatively with nearby communities. The advantages of combining your recyclables with those from other programs are:

- obtaining economy of scale in collection, processing and marketing;
- more frequent shipments to the market; therefore, less storage space is required; and
- the ability to command a better price for the feedstock.

6. Contamination

Designing collection containers so that the contents are easily visible to the public will help to avoid contamination. If the public is made aware that the container is not for trash but for the collection of specific types of recyclables, there will be less opportunity for contamination.

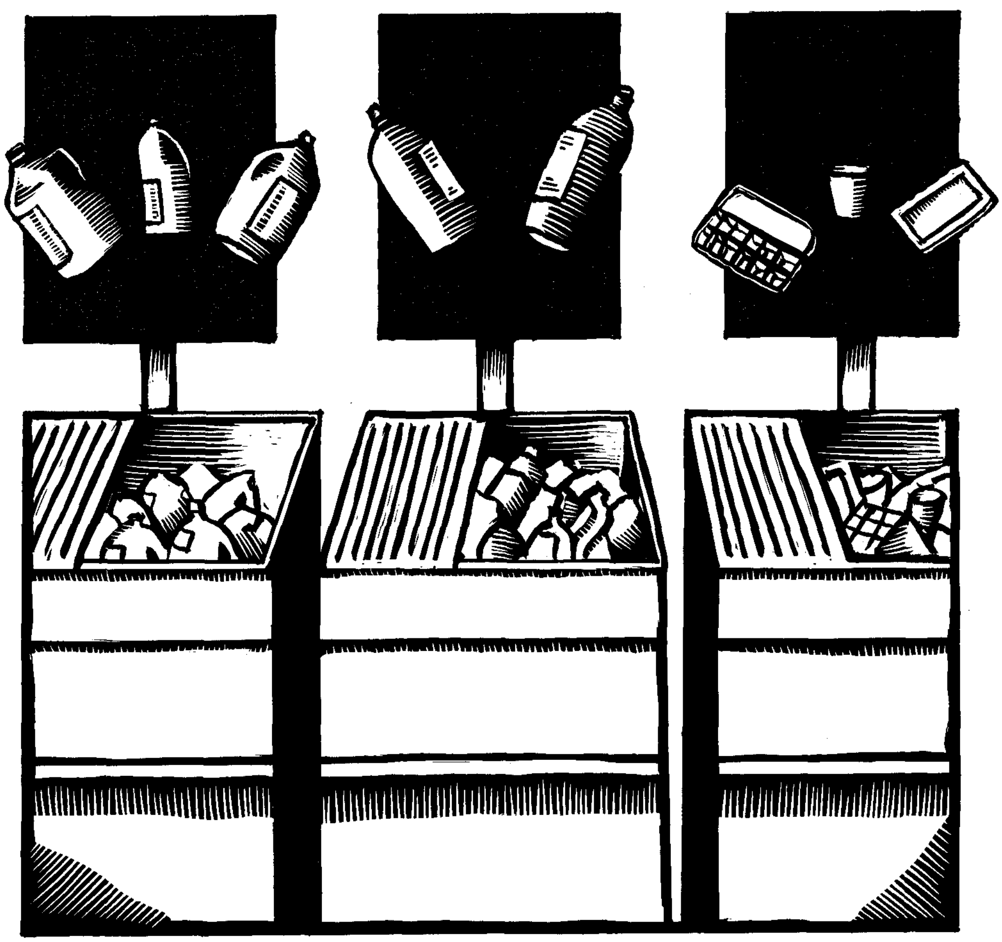
Drop-off sites have the potential for substantial contamination if the collection is not monitored. Avoid unnecessary contamination by employing a staff and educating them about plastics recycling.

Also, display samples of the types of containers being recovered. Many people look in the bin to see what is already there instead of reading signs. Therefore, it is very important to keep the plastic recyclables clean. Once one contaminant gets in the bin, more are likely to follow.

7. Signs and sample recyclables

Good signs are essential! Signs should be clear, durable, weather-proof and official-looking. Signs that look "official" rather than homemade are taken more seriously.

For more information on successful rural recycling program designs, contact the Council for Solid Waste Solutions.



What Are the Economics of Implementing Plastics Recycling?

The following are recommendations on how to accurately assess and equitably distribute the costs of and the credits accruing from collecting recyclable plastics or other recyclable materials.

1. Assess costs by volume

The costs associated with collection labor and equipment, transportation, and landfill disposal are all related to *volume* handled. Collection trucks fill up because they have reached capacity—their volumetric carrying capacity has been filled—not because they are overweight. Understanding this, the importance of densifying plastics and/or other recyclables becomes clear.

2. Labor is the highest expenditure

Any steps that can be taken to reduce the labor (handling of materials) will have a positive impact on the overall economics of recycling. A full accounting of all taxes and fringe benefits associated with hourly wages or salaries is necessary to assess true total labor costs. Typically the full cost is 30 to 50 percent over the hourly wage.

3. Figure in costs to prepare and deliver material to market

Estimating collection alone will not give an accurate picture of costs and can lead to false conclusions and ineffective systems. Program planners should determine **all** costs associated with collection, processing and transportation, from the point of collection to the point of deposition at the market.

Calculating System Costs

There are at least two commonly used methods for calculating system costs. The worksheets on the following pages will allow you to determine your total annual recycling system costs, as well as the *fully allocated, average cost per ton* for each material in your existing or planned recycling program. On pages 52 to 55, we've filled out some of the worksheets for you. These calculations are based on figures for a midwest town with a population of 48,000. Your figures will vary, but this example should help answer any questions you may have along the way. A more complicated method involving a computer model also is available which allows you to calculate the *incremental cost of recycling plastics* or any other recyclable material. If you are interested in receiving more information about this and other computer models, please fill out and mail the card at the end of this manual.

Communities and recyclers who need assistance in assessing costs may also seek advice from private contractors, state and local governmental agencies and professional waste management consultants.

Total Annual Recycling System Costs

Use this section to tabulate the annual cost of collection, processing and transportation to market using worksheets A through F on the following pages. For example, to determine the cost to be included on line (A), complete worksheet (A) and carry the total to the appropriate line.

The annual cost of collection	$__________	(A)
Plus the cost of processing	+ $__________	(B)
Plus the cost of transportation to market	+ $__________	(C)
Minus the total revenues received from the sale of each recyclable material	− $__________	(D)
Minus the savings from reduced refuse collection costs (based on the volume diverted from the refuse collection route)	− $__________	(E)
Minus the savings from reduced refuse tipping fees (based on the volume saved if landfilling, tonnage if incinerating)	− $__________	(F)
Equals the net annual cost/savings of recycling	= $__________	

(A) To Determine the Annual Collection Costs:

Operating Costs

1. Labor (wages, taxes, benefits)[1] $__________

2. Plus all vehicle operating/maintenance costs[2] + $__________

3. Plus other collection/storage equipment (e.g., drop boxes) maintenance costs + $__________

4. Plus education/promotion costs + $__________

5. Plus overhead and other operating costs[3] + $__________

Equals total operating costs = $__________

Capital Costs (amortized)

6. Collection trucks $__________

7. Plus specialized equipment[4] + $__________

8. Plus household set-out bins or bags[5] + $__________

9. Plus storage containers (e.g., drop boxes) + $__________

10. Plus other capital costs + $__________

Equals total capital costs (amortized) = $__________

Total annual collection costs
(sum of operating and capital costs) = $__________ (A)

(B) To Determine the Annual Processing Costs:

Operating Costs

11. Labor (wages, taxes, benefits)[6] $__________

12. Plus equipment maintenance costs + $__________

13. Plus building maintenance costs + $__________

14. Plus other operating costs[7] + $__________

Equals total operating costs = $__________

Capital Costs (amortized)

15. Buildings[8] $__________

16. Plus baler and other processing equipment[9] + $__________

17. Plus other capital costs[10] + $__________

Equals total capital costs (amortized) = $__________

Total annual processing costs
(sum of operating and capital costs) = $__________ (B)

---

[1] Include administrative costs.
[2] Include insurance, registration, fuel, lubricating fluids, parts, repairs.
[3] Such as supplies, miscellaneous hand tools, safety equipment and insurance.
[4] Such as plastics densification equipment.
[5] Include replacement costs and distribution costs.
[6] Include administrative costs.
[7] Such as supplies, miscellaneous hand tools, safety equipment, utilities, insurance and residue disposal costs.
[8] Include land, buildings, and site improvements, amortized over 20 years if owned, [illegible]

(C) To Determine Transportation Costs:

Transportation costs for individual materials typically will be paid as a service fee to a trucking company or be "paid for" through a reduction in market price paid.

(D) To Determine Revenues:

For each collected material, multiply the annual tonnage anticipated by the expected market value per ton. (For plastics, see calculations on page 23.)

(E) To Determine Savings from Reduced Refuse Collection:

By diverting recyclables from the waste stream, there is less refuse requiring collection and subsequent transportation to the landfill or incinerator. Refuse collection trucks do not fill to capacity as quickly and can therefore remain on their routes longer and cover a greater number of stops (each having less refuse due to recycling) in a workday.

By removing difficult-to-compact recyclables such as plastics or corrugated cardboard, compaction is more efficient and allows for even higher tonnage collected per load. If fewer trucks and personnel are needed to collect refuse, credit can then be taken for any reduction in labor and/or equipment.

If the refuse and recyclable materials haulers are different organizations, savings will not be realized from reduced refuse collection. This is one of the reasons why it is so important to integrate collection of recyclables into the existing solid waste management system.

(F) To Determine the Savings from Reduced Refuse Disposal:

If disposal is performed under contract with a separate organization, fees will typically be assessed by cubic yard or ton. Credit should be taken for each unit (cubic yard or ton) which is diverted from the waste stream.

If Refuse Is Landfilled:

Determine how much each cubic yard of landfill space costs. Include the amortized capital costs of land; landfill development costs, and equipment (bulldozer, compactors) costs; estimated final closure of the landfill divided by the estimated lifetime capacity; post-closure costs; operating and maintenance costs (including labor, equipment, monitoring and environmental controls). Some organizations also include the "heirloom" costs (the loss of landfill property for future use).

Estimate the volume (cubic yards) of material diverted from the waste stream by recycling and multiply it by the total cost per cubic yard of the landfill.

18. Volume of material diverted from the waste stream (cubic yards) ____________

19. Multiplied by cost per cubic yard of the landfill x $____________

Equals the savings from reduced disposal =$____________ (F)

If Refuse Is Incinerated:
Determine the tipping fee charged per ton at the incinerator. Estimate the tonnage of material diverted from the waste stream by recycling and multiply it by the total cost per ton charged by the incinerator operator.

20. Tonnage of material diverted from the waste stream	______
21. Multiplied by cost per ton of incineration	x $______
Equals the savings from reduced disposal	= $______ (F)

Fully Allocated Costs of Various Recyclable Materials

Having now calculated total annual recycling system costs, the next step is to equitably allocate these costs among all of the recyclables collected. Slightly different approaches are required for commingled and separated material collection systems.

To determine what portion of the total recycling program costs should be allocated to the collection of each recyclable material (e.g., steel, aluminum, plastic, paper, glass) complete the following worksheets:

Commingled Material Collection

22. Annual collection costs	$______ (A)	
23. Multiplied by the percent of the collection vehicle capacity devoted to (name of material)	x ______ (G)	
24. Equals the annual collection cost of (name of material)		= $______
25. Plus cost to process (name of material)		+ $______ (H)
26. Plus cost to transport (name of material)		+ $______
27. Minus revenue from the sale of (name of material)		− $______
28. Minus the savings from reduced refuse collection		− $______ (E)
29. Minus the savings from reduced refuse disposal		− $______ (F)
Equals the net cost (savings) to recycle a particular recyclable material on an annual basis		= $______

Source Separated Material and Curb Sort Collection

30. Collection equipment costs *(add lines 2 and 6)*	$__________	
31. Multiplied by the percent of the collection vehicle capacity devoted to (name of material)	x__________ (G)	
32. Equals the collection equipment cost to be allocated to (name of material)		=$__________
33. Plus the amortized cost of densification and/or storage equipment specifically for (name of material)[1] *(from line 7 or 9)*		+$__________
34. Equals the total equipment cost allocated to (name of material)		=$__________
35. Total annual collection labor costs *(from line 1)*	$__________	
36. Multiplied by the percent of on-route collection time devoted to (name of material)	x__________ (I)	
37. Equals the labor cost allocated to (name of material)		=$__________
38. Plus (name of material)'s share of fixed costs *(add lines 4, 5 and 8, then divide sum by total number of separated recyclable materials collected)*		+$__________
39. Equals total collection cost for (name of material) *(add lines 34, 37 and 38)*		=$__________
40. Plus the cost to process (name of material)		+$__________ (H)
41. Plus the cost to transport (name of material)		+$__________
42. Minus the revenue from the sale of (name of material)		−$__________
43. Minus the savings from reduced refuse collection		−$__________ (E)
44. Minus the savings from reduced refuse disposal		−$__________ (F)
Equals the net cost (savings) to recycle (name of material) on an annual basis		=$__________

(G) To Determine What Percentage of the Usable Body Capacity of Curbside Recycling Collection Truck to Allocate to Each Recyclable Material:

Divide the space required to accommodate a particular material by the total usable capacity of the vehicle. For example, if an on-board plastics compactor occupies three cubic yards on a truck with a total usable capacity of 30 cubic yards, then 3 divided by 30 or 0.1 (10 percent) of the total truck costs should be allocated to plastic.

(H) To Estimate the Cost of Processing a Particular Material:

The cost of processing materials should be figured on a tonnage basis. (Processing facilities measure their flow-through in tons-per-hour or tons-per-day.)

45. Total procesing costs	$________ (B)	
46. Minus all single material equipment costs[1]	−$________	
47. Minus total labor costs used for only one material[2]	−$________	
48. Equals the total shared processing costs		=$________
49. Multiplied by percent that (name of material) comprises of total annual tonnage processed	x________	
50. Equals (name of material)'s share of processing costs		=$________
51. Plus (name of material) equipment costs		+$________
52. Plus (name of material) labor costs		+$________
Equals total processing costs for (name of material)		=$________ (H)

(I) To Estimate the Percentage of the Labor Cost on the Collection Route Devoted to the Collection and/or Separation of Each Recyclable:

It is useful to do a time study to determine the exact percent of time devoted to each recyclable material collected in any collection program.

Time studies of curbside sort systems that collect newspaper, flint glass, amber glass, green glass, tin, aluminum and mixed HDPE-PET plastics reveal that 12 percent of the collection time is devoted to plastic and 30 percent to glass. Thus, in this case, 12 percent and 30 percent of the total labor costs should be allocated to the collection of plastics and glass, respectively.

Sample Worksheets from Anytown U.S.A.

Collection

Anytown is a community of 48,000 people in the Midwest that recently implemented a multi-material curbside recycling program. Recyclables are picked up weekly at curbside where they are sorted by the collection truck driver. There are about 18,000 households in the town, and 65 percent of these households participate in the program each week.

Recyclable materials are collected in six 30-cubic-yard trucks, each with a single-person crew. The trucks cover 600 homes on their daily routes, making 390 stops per day. Each truck is equipped with a plastics compactor.

Material Collected	Pounds per Day *(per truck)*	Truck Capacity Used *(cubic yards)*
Aluminum	40	1.0
Clear glass	900	3.5
Green glass	300	1.0
Brown glass	200	0.5
HDPE & PET plastics	270	3.0
Newspaper	3,900	16.0
Steel cans	390	5.0
	6,000	30.0

Processing

Anytown's collection contractor processes 18 tons of recyclable material each day. This equates to 4,680 tons per year from Anytown's six collection routes. Glass is dumped directly from the collection trucks into roll-off boxes. All other materials are baled.

Material	Tons per Year
Aluminum	31.2
Glass	1,092.0
Newspaper	3,042.0
HDPE/PET (mixed)	210.6
Steel	304.2
Total materials handled	4,680.0

Transportation costs

All of Anytown's markets are one hour's drive from the processing facility and transportation costs are $100 per roundtrip.

Revenues

Calculations are based on prices quoted for the "East-Central" part of the country in the December 4, 1990 issue of *Recycling Times.*

Material	$ per Ton
Aluminum	610
Glass	15
Newspaper	15
HDPE/PET (mixed)	90
Steel	60

Savings from reduced refuse collection

Refuse collection costs in Anytown are $60 per ton ($24 per cubic yard). Typically, an efficient refuse collection organization will be able save 50 percent of its collection costs for each cubic yard of recyclable material it diverts from the refuse stream. Thus, a collection credit of $12 can be given for each compacted cubic yard of material collected as recyclables, rather than refuse.

Savings from reduced refuse disposal

(A) To Determine the Annual Collection Costs: (per truck)

Operating Costs

1. Labor (wages, taxes, benefits)[1] $ 26,000
2. Plus all vehicle operating/maintenance costs[2] +$ 12,000
3. Plus other collection/storage equipment (e.g., drop boxes) maintenance costs +$ —
4. Plus education/promotion costs +$ 3,000
5. Plus overhead and other operating costs[3] +$ 15,000

Equals total operating costs =$ 56,000

Capital Costs (amortized)

6. Collection trucks $ 13,000
7. Plus specialized equipment[4] +$ 1,500
8. Plus household set-out bins or bags[5] +$ 2,500
9. Plus storage containers (e.g., drop boxes) +$ —
10. Plus other capital costs +$ 5,000

Equals total capital costs (amortized) =$ 22,000

Total annual collection costs
(sum of operating and capital costs) =$ 78,000 (A)

(B) To Determine the Annual Processing Costs:

Operating Costs

11. Labor (wages, taxes, benefits)[6] $ 54,000
12. Plus equipment maintenance costs +$ 10,000
13. Plus building maintenance costs +$ 3,000
14. Plus other operating costs[7] +$ 26,000

Equals total operating costs =$ 93,000

Capital Costs (amortized)

15. Buildings[8] $ 25,000
16. Plus baler and other processing equipment[9] +$ 13,000
17. Plus other capital costs[10] +$ 12,000

Equals total capital costs (amortized) =$ 50,000

Total annual processing costs
(sum of operating and capital costs) =$ 143,000 (B)

---

[1] Include administrative costs.
[2] Include insurance, registration, fuel, lubricating fluids, parts, repairs.
[3] Such as supplies, miscellaneous hand tools, safety equipment and insurance.
[4] Such as plastics densification equipment.
[5] Include replacement costs and distribution costs.
[6] Include administrative costs.
[7] Such as supplies, miscellaneous hand tools, safety equipment, utilities, insurance and residue disposal costs.
[8] Include land, buildings, and site improvements, amortized over 20 years if owned, annual rental otherwise.

Source Separated Material and Curb Sort Collection

30. Collection equipment costs *(add lines 2 and 6)* — $25,000

31. Multiplied by the percent of the collection vehicle capacity devoted to ~~(name of material)~~ plastic — x 10% (G)

32. Equals the collection equipment cost to be allocated to ~~(name of material)~~ plastic — =$ 2,500

33. Plus the amortized cost of densification and/or storage equipment specifically for ~~(name of material)~~ plastic *(from line 7 or 9)* — +$ 1,500

34. Equals the total equipment cost allocated to ~~(name of material)~~ plastic — =$ 4,000

35. Total annual collection labor costs *(from line 1)* — $26,000

36. Multiplied by the percent of on-route collection time devoted to ~~(name of material)~~ plastic — x 12% (I)

37. Equals the labor cost allocated to ~~(name of material)~~ plastic — =$ 3,120

38. Plus ~~(name of material)~~ plastic's share of fixed costs *(add lines 4, 5 and 8, then divide sum by total number of separated recyclable materials collected)* — +$ 2,929

39. Equals total collection cost for ~~(name of material)~~ plastic *(add lines 34, 37 and 38)* — =$ 10,049

40. Plus the cost to process ~~(name of material)~~ plastic — +$ 1,430 (H)

41. Plus the cost to transport ~~(name of material)~~ plastic
4 loads x $100/load — +$ 400

42. Minus the revenue from the sale of ~~(name of material~~ plastic
35.1 tons x $90/ton — -$ 3,159

43. Minus the savings from reduced refuse collection
$12/yd x 234 cubic yards of plastic recycled — -$ 2,808 (E)

44. Minus the savings from reduced refuse disposal
$50/ton x 35.1 tons — -$ 1,755 (F)

Equals the net cost (savings) to recycle (name of material) on an annual basis (per truck) — =$ 4,157

$4,157/35.1 tons = $118.43

(H) To Estimate the Cost of Processing a Particular Material:
The cost of processing materials should be figured on a tonnage basis. (Processing facilities measure their flow-through in tons-per-hour or tons-per-day.)

45. Total procesing costs	$143,000 (B)	
46. Minus all single material equipment costs[1]	–$______	
47. Minus total labor costs used for only one material[2]	–$______	
48. Equals the total shared processing costs		=$143,000
49. Multiplied by percent that (~~name of material~~ plastic) comprises of total annual tonnage processed	x 6%	
50. Equals (~~name of material~~ plastic)'s share of processing costs		=$8,580
51. Plus (name of material) equipment costs		+$______
52. Plus (name of material) labor costs		+$______
Equals total processing costs for (~~name of material~~) plastic		=$8,580 (H)

÷ 6 trucks = $1,430/truck

[1] Estimate the amortized cost for ...

Implement an Effective Community Education Campaign

The success of a community recycling program hinges upon public participation and acceptance. Plastics recycling is still in its infancy but is growing by leaps and bounds. Nonetheless, there are still many myths about plastics that need to be dispelled. Education about plastics recycling is the key to participation and support.

Most citizens are ready to recycle plastics. They view plastics recycling as an important way to:

conserve landfill space;
conserve the use of nonrenewable resources; and
take personal action to address environmental concerns.

An Effective Public Education Program Should Have Three Stages:

1. Initial announcement

Inform the public that the program will be starting on a specific date in the near future.

Public service television and radio announcements, newspaper articles, and handbills are effective. Communicate with young residents through the public and private school systems.

> CAUTION: Two weeks' advance notice is recommended. Do not allow too much lead time or residents may save up very large quantities of materials, and the program may be swamped during the first few weeks.

2. Kickoff campaign

Plan to begin the program with a substantial promotional campaign. Coordinate press, radio, and local TV coverage.

Get local politicians and celebrities involved.

A successful start means making sure that the community sees, reads, and hears about the program and knows how to do what is expected of them.

Above and on the next page are examples of clear and effective education literature. Pictures play a large role in reinforcing the message. Also, naming the specific uses of plastics containers that may be recycled – and those that may not be included – is extremely helpful for residents.

3. Continued education and reminders

Remind residents about how and why they should participate and reinforce recycling habits by providing them with feedback on the results of their efforts (such as tons collected and money saved).

An Effective Education Program Includes Four Key Principles:

1. Project identity

Project identity promotes recognition and positive feelings about recycling and the local hometown program.

A logo is a good example of an aid to attract the attention of local residents. Use the logo for promotional materials, videos, signs for local drop-off centers, collection vehicles, household containers, employee uniforms, etc.

2. Consistency

Consistent information demands extensive planning. A plan that is introduced to the public and reinforced over time without major changes will maximize the level of participation. Conversely, frequent alterations to the collection program rules may produce confusion and decrease the level of participation.

3. Clarity

Information should be comprehensive but easy to understand. Instructions should be reinforced through pictures and graphics.

Use big pictures and small words. Most people will look at the instructions for a very brief time, perhaps 10 to 15 seconds. Clear and simple recycling instructions will enhance participation and the quality of the collected materials.

Basic information a plastics collection program should cover:

What materials should be set out?

(Provide specific lists of products that should be included and those that should be excluded.)

How should they prepare the material?

Remove the caps?

Rinse the containers?

Separate the materials?

Squash the bottles?

When should they set the materials out?

Where should they take materials (for drop-off programs)?

Who should they call for more information?

Consider giving a telephone number to call for those citizens who are interested in learning more about the technical aspects of the program.

Include These Kinds of Plastic Bottles:

KITCHEN
- Pop
- Milk
- Water
- Juice
- Syrup
- Ketchup
- Cooking oils

BATHROOM
- Shampoo
- Conditioner
- Cosmetics
- Pill bottles
- Lotions

LAUNDRY
- Liquid laundry detergent
- Bleach
- Fabric softener

HOUSEHOLD CLEANERS
- Liquid dish detergent
- Liquid household cleaners (window, bathroom & kitchen cleaner)

AUTOMOTIVE
- Windshield washer
- Antifreeze
- Motor oil bottles (do not rinse, drain bottles thoroughly when emptying and take used oil to recycling center)

Don't Include These Kinds of Plastic Items:

- Bags & wrap
- Caps & lids
- Toys
- Medical supplies
- Large plastic items
- Pesticides & herbicides
- Solvents, paints & adhesives
- Jars & tubs such as peanut butter, yogurt and margarine
- Pails such as ice cream
- Flower pots & garden plastics
- Microwave containers

These plastic items will not be collected at this time.

4. Professional approach

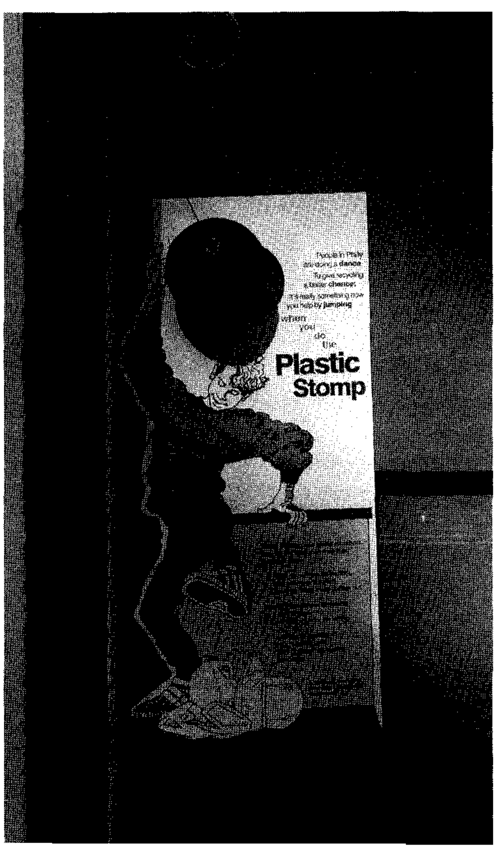
A professional approach is crucial to the success of an educational program. Professional-looking education and promotion materials will capture the public's attention and justify the request for a long-term commitment from residents. Remember, other professionally designed and produced materials are competing for the public's attention.

Effective approaches to implement public education programs include:

- a durable list of DOs and DON'Ts for quick reference;
- brochures with drawings and photographs;
- refrigerator magnets naming items that the program will accept and will not accept;
- endorsements of the program by local "celebrities";
- news coverage in print, on radio, and cable TV;
- door hangers with reminder messages about the program;
- bookmarks distributed through the public library and schools; and
- education tags (hang-tags) for household collection containers that have boxes for route drivers to check off instructions to residents.

Develop relationships with other local and state officials. They are sensitive to the same kinds of community concerns in the area.

Much of the action on municipal solid waste management occurs at the city and county level. Take the time to meet all of the officials in the community who make decisions about municipal solid waste management and learn their positions on the issues. These people include: county board members, city council members, local environmental protection officials, waste management officials and executive officials such as the city mayor and the deputies who serve these officials.



Help from the Council for Solid Waste Solutions

The Council for Solid Waste Solutions has a toll-free telephone number for people who wish to obtain information on plastics recycling and other solid waste management options.

The number is **1-800-2-HELP-90.**

The Council has a **Resource Center** that provides news, legislative and technical information on all aspects of plastics in the waste stream. This database can be accessed by anyone with a phone modem on his personal computer. The Resource Center has corporate and nonprofit subscription rates and a minimal on-line user fee.

The Council maintains an extensive library and offers a range of print and media materials including a 12-minute video "Plastics Recycling Today: A Growing Resource." Specific fact sheet topics range from information on specific resins to community curbside separation programs to general industry recycling efforts. The Council also offers a variety of products for junior high and high school students and teachers.

If you or other community leaders are considering new policies for dealing with solid waste, call the Council for assistance in arranging for an expert speaker on the subject. Speakers can address legislative assemblies, university audiences, or civic organizations. The Council can also put you in touch with experts who can discuss equipment needs, collection systems, and offer other technical advice.

For further information from the Council for Solid Waste Solutions or to receive an order form for the materials described above, please call or write the Council for Solid Waste Solutions at 1275 K Street, N.W., Suite 400, Washington, DC 20005.

Appendix A
Where Plastics Come From[1]

Today, a minimum of 12,000 companies in the United States make plastics their business. Some produce basic materials with plastics, while others process or fabricate plastics into products or parts.

Manufacturers use chemical reactions to transform basic feedstocks (monomers) from natural gas and crude oil into plastics materials (polymers or resins). These plastics are then sold in the form of granules, powder, pellets, flakes, or liquids for eventual processing into finished products.

Intermediate processing steps involve adding modifiers to the resins to impart special properties; plastics can be dyed, made more flexible, stronger, or more resistant to heat, light or impact.

Plastics processors turn the material into secondary products (film, sheet, rod, tube), component parts or finished end-products. Fabricators turn secondary products into end-products.

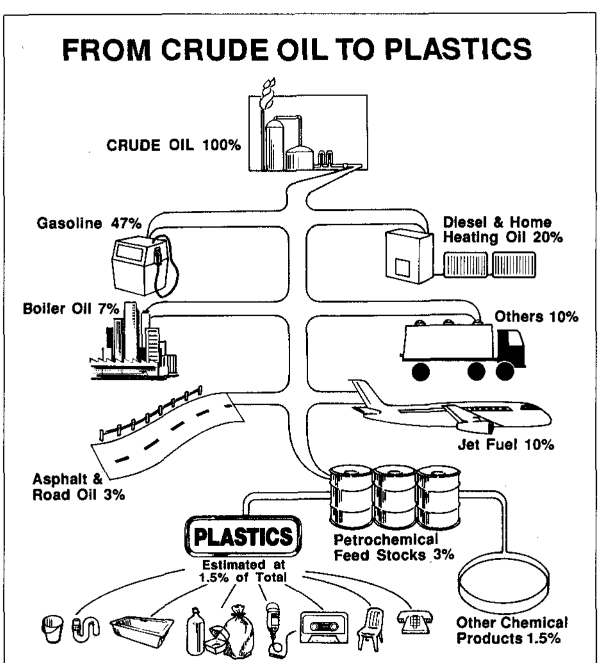
All about plastics

Many plastics are derived from fractions of petroleum or gas that are recovered during the refining process. For example, ethylene monomer (one of the most important feedstocks or starting materials for plastics) is derived, in a gaseous form, from petroleum refinery gas, or liquefied petroleum gases, or liquid hydrocarbons.

Although petroleum or gas derivatives are not the only basic source that is used in making feedstocks for plastics, they are among the most popular and economical today.

Coal is another excellent source in manufacturing of feedstocks for plastics. Other adaptable materials include agricultural oils like castor oil or tung oil derived from plants.

From these basic sources come the feedstocks, called monomers. The monomer goes through a chemical reaction (polymerization) that causes the small molecules to link together into ever-increasing longer molecules.



Source: U. S. Energy Information Administration, *Petroleum Supply Annuals*

Chemically, the polymerization reaction links the monomer into a long polymer chain. A polymer is a high molecular weight compound that contains comparatively simple recurring units.

When styrene monomer is polymerized, it becomes a styrene polymer or polystyrene. The ethylene monomer can be polymerized to produce ethylene polymer or polyethylene.

Plastics are a composite of materials with distinct and special advantages. Whatever their properties or forms, most plastics fall into one of two groups—the thermoplastics or the thermosets. Both thermoplastics and thermosets are fluid when molded or formed.

Thermoplastics solidify by cooling and can be remelted repeatedly, like water, which can freeze, thaw and freeze again.

Thermosets are hardened by further chemical reaction called crosslinking. Reheating can soften the material but it will not restore its flowability, as an egg can be hard boiled but not made into a raw egg again.

There is a great deal of flexibility in the plastic manufacturing process for creating a wide range of materials. The way in which the small molecules link together into larger molecules and the structural arrangement they take (packed closely together or separated by side protrusions or branches) is one determinant of the density of the plastic.

Other determinants include the length of molecules in the polymer chain (molecular weight) and the type of molecules.

Polymerizing two or more different monomers together (called copolymerization) and incorporating chemicals or additives during or after polymerization are other ways of modifying resin characteristics.

Turning the polymer into a product

After polymerization, the polymer (plastic resin) is prepared for use by the processor. In some instances, it is possible to use the plastic resin as it comes out of the polymerization reaction. More often, however, it goes through other steps that put it into a form that can be more easily handled by the processor and more easily run through processing equipment.

The most popular solid forms for plastic resin are pellets, granules, flakes or powder. In the hands of the processor, these solids are generally subjected to heat and pressure, melted, forced into the desired shape, then allowed to cure and cool into a finished product.

Liquids can also be used to impregnate fibrous materials that are then allowed to harden into reinforced plastics.

Another option available to processors is to use resin incorporating a blowing agent. Subjected to the heat of processing or the heat from the chemical reaction, these agents decompose and release gases that can turn a solid product into a foamed product.

To summarize, the flow from basic feedstock to end-product generally proceeds along these lines: feedstocks (monomers) are polymerized by chemical reaction into polymers (or plastics resins). The resins are then made into forms useful for processing (sometimes called molding or extrusion compounds). The compound then goes to the processor, who has several techniques available for turning the resin into a finished secondary product, such as sheet, rod, tubing, and shapes, or into coating or surfacing.

Appendix B
Balers for Plastics Recyclers[1]

The addition of plastics in recycling operations has placed new performance requirements on traditional baling equipment. This section presents features that are important in selecting the appropriate baling equipment for a small recycling operation.

One of the largest challenges to recycling plastics is the wide variety of resins and containers that are manufactured out of single, multiple, and multilayered resins.

Today, new markets for commingled plastics have emerged to join the more established single resin markets such as HDPE and PET.

Recycling centers can perform any of the following processes in order to prepare their material for plastics processing: sorting, baling, shredding, and granulation. The particular combination of processes used by a center depends on a specific market's needs for its materials.

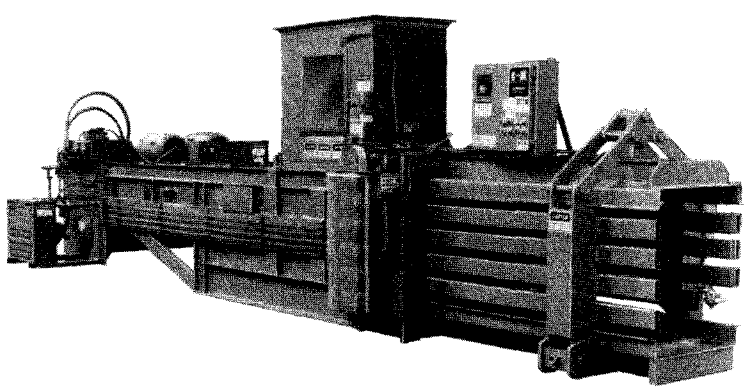
Sorting is performed by the majority of recycling centers because it conforms the material to market requirements by both type and quality of resins.

Baling is preferred over granulation because it allows processors to correct small deviations from quality guidelines. Baling plastics is the most cost-effective means of handling them in a drop-off program that has the ability to process materials. Baling allows one-time handling of the material, puts it in a form that is the industry standard—ready for shipment to market, and allows the purchase of equipment that can have multiple applications at the recycling center.

In most processing operations, there are no capabilities to mechanically separate resins collected from households. State-of-the-art sorting and quality control still involve a conveyor requiring substantial manual labor. An error in sorting materials at the recycling center is much easier to correct at a plastics processor if the material arrives in baled rather than granulated form.

Types of balers

Balers are grouped in two major design categories: horizontal and vertical (or downstroke). The direction in which the compacting ram moves defines the type of baler. Each of these baler types has characteristics that make it more efficient for certain applications.



(A) Horizontal Balers:
Within this category, balers have either a closed or open end. In closed-end balers, the baling force is exerted against a door that is opened to eject the finished bale. Open-end balers have a long ejection chamber where pressure from the side walls holds a finished bale to provide a surface to compress the material against. These balers have automatic or semiautomatic tying devices that provide a fully automated, continuous operation.

Bale size (typical):	30″ x 40″ x 72″ or 40″ x 48″ x 72″
Bale weight:	700 to 1800 lbs. depending on plastic density and baler compaction pressure
Power requirements:	30 to 150 horsepower
Cost:	$30,000 to $150,000
Advantages:	Higher production (three to ten bales per hour) Higher bale density
Disadvantages:	Requires large floor space for operation and material storage May require specialized assembly and/or maintenance More difficult to operate Greater safety precautions required Cost

(B) Vertical Balers (downstroke balers):
Vertical balers are preferred in small operations. This type of baler has been primarily designed and used for baling cardboard, rags, paper and plastic film in manufacturing operations and supermarkets to reduce the volume of waste generated internally.

Bale size:	30″ x 48″ x 60″
Bale weight:	600 to 1000 lbs. (for cardboard) 350 to 650 lbs. (for plastic)
Power requirements:	10 to 20 horsepower
Cost:	$8,000 to $15,000
Advantages:	Requires less than 100 square feet of total operating space Does not require specialized assembly or maintenance Simple and safe operation Cost
Disadvantages:	Slow production (two to three bales per shift) Low bale density

Some problems with vertical balers for plastic containers have occurred where they were heavily used in recycling centers. These problems included low production rate, clumsy material handling and low density of the bales. The low throughput (production rate) is attributed to the combination of the bulk density of the uncrushed plastic containers fed into the baler and the springback effect of plastic. However, a properly selected vertical baler can be more cost effective than a horizontal baler.

Choosing the right baler

In selecting the appropriate baler for the operation, consider three criteria:

Density
Size of the bale (rather than total weight of the bale)
Throughput (the number of bales required per day)

Whether the operation is one- or two-shift, the equipment should ideally operate 100 percent of the time less whatever time is required for maintenance. Purchasing equipment that will be idle much of the time is not cost effective.

(A) Density:

Transportation costs decrease as bale densities increase. Most plastic processors require truckload quantities (30,000 to 40,000 lbs.) in order to ensure efficient use and low-cost transportation. Therefore, bale density must be considered along with bale size.

For a typical export size bale, 30″ x 48″ x 60″, 48 bales can be loaded in a 48-foot trailer. Each bale must weigh 750 pounds to yield a 36,000-pound truckload. Therefore the required density is:

$$\text{Density: } \frac{750 \text{ pounds}}{50 \text{ cubic feet}} = 15 \text{ pounds per cubic foot}$$

Higher densities are desirable since a truckload can weigh as much as 40,000 pounds and still meet Department of Transportation safety standards.

Bale density is directly related to the compaction pressure on the platen (face plate) of the baler. Platen pressure is measured by dividing the maximum cylinder force in pounds by the surface of the platen in square inches. The cylinder force depends on the hydraulic pressure of the system. Typical numbers for platen pressure range between 25 to 75 psi.

(B) Size:

The bale size is important in any operation where the baler is used for more than one material, as is the case in most recycling centers. The larger the bale, the more space required for temporary storage of uncrushed material while the baler is tied up with another material. For example, if PET soft drink bottles and HDPE milk jugs are baled separately and the baler is also used for cardboard, then the required storage space for uncrushed bottles is as follows:

PET bale weight:	750 pounds
PET bottle density:	30-45 pounds per cubic yard
Required space:	16-25 cubic yards
HDPE bale weight:	750 pounds
HDPE milk jugs density:	20 pounds per cubic yard
Required space:	25-30 cubic yards

For this type of operation, a smaller bale is recommended (provided it is acceptable by the market) since it requires less storage space and allows more flexibility of operation. Freight cost will not be affected if the density of the bale is adequate. Remember, however, to always consider possible future expansion of your plastics capacity.

(C) Throughput:

Production rate depends on the cycle time and the chamber loading time.

Cycle time is dependent on the hydraulic package provided with the unit. For most balers, the cycle time increases as the baler cavity fills. Usually manufacturers list average cycle time under no load. Typical cycle times with no load range from 40 to 60 seconds. Actual cycle times can be expected to be longer.

The loading chamber is the area where the recyclable material is placed for baling. This space is dependent on the size of the platen, the stroke of the cylinder, and the control over the springback effect of plastics.

Unlike metal containers, plastic containers tend to regain part of their original shape after the compacting pressure is removed. This characteristic of plastics is called "memory." Reexpansion can be as much as 50 percent of the compacted volume. This reduces the loading efficiency of the baler.

Loading is the most time-consuming segment of the baling cycle. The design of the baler should allow for an automated conveyor feeding system. Use of plastic bottle crushers and perforators prior to loading the baler will increase productivity and help ensure the desired bale density.

In such a system, production can be increased to seven or eight bales per eight-hour shift. An efficient system, properly loaded, equates to approximately 3,500 pounds of baled plastics each day or 910,000 pounds of baled plastics each year (assuming a one-shift-per-day/five-day-week/52-weeks-a-year operation).

A complete comparison of the operation of a horizontal and vertical baler should include labor cost, utilities, maintenance, and depreciation cost.

In general, unless several bales per hour are required, a system with a small vertical baler will be more advantageous.

Conclusion

A small vertical baler system should be considered for production rates up to 3,000 lbs. per eight-hour shift. The advantages are:

Low initial cost;
Easy to assemble, operate, and maintain;
Low power requirements;
Minimal floor space usage; and
Better multi-material flexibility.

Balers Suitable for Plastic Containers

The following is a partial list of balers that are successfully baling plastic in one or more recycling programs in North America. This list is not comprehensive; it represents balers that are known at this time to satisfactorily bale plastic.

In order to achieve maximum density and efficiency, all caps should be removed. Balers should be operated indoors. They operate best when the hydraulic system is warm. If heating an entire building is not possible, local heaters can be used to warm the baler area. We recommend that information be obtained from several manufacturers before committing to any particular baler.

VERTICAL

EPCO 21 or 31
EPCO Manufacturing
860 Seneca Street
Buffalo, NY 14210
Contact: Peter Hurd
716/852-2234
800/836-BALE

Model LC-60-HD
International Baler Corporation
P.O. Box 6922
Jacksonville, FL 32236
Contact: Waunita Frazier
800/231-9286

Model 5000
Philadelphia Tramrail
2207 E. Ontario St.
Philadelphia, PA 19134
Contact: Lloyd Peterson
507/886-6666

Frontier Recycling Systems, Inc.
3310 N. Oakley Avenue
Chicago, IL 60618
Contact: Sergio Firpo
312/525-6060

Selco Products
Model V-5-XHD
Model H-AL-7RP
P.O. Box 401, Jekyll Road
Baxley, GA 31513
Contact: Steve Coleman
912/367-4661

National Baling Press
HY-A & L series
99 Tulip Avenue, Suite 303
Floral Park, NY 11001
Contact: Steven Frechtman
516/354-1212

HORIZONTAL

Logemann Brothers Co.
3150 W. Burleigh Street
Milwaukee, WI 53210
Contact: Robert Plichta
414/445-3005

International Baler 1440
International Baler Corp.
P.O. Box 6922
Jacksonville, FL 32236
Contact: Rick Odum
904/357-3812

Balewel/Balemaster 1800 series
Balewel/Balemaster
9890 Crown Court
P.O. Box 465
Crown Point, IN 46307
Contact: Cornel Raab
219/663-4525

American/Economy "Big Bite" Baler
Model 5042
American Baler Company
608 Hickory Street
Bellevue, OH 44811
Contact: John Russell
419/483-5790

VERTICAL AND HORIZONTAL

Harris Group
2520 Broadway NE
Minneapolis, MN 55413
Contact: Michael Okerstrom
612/627-0260

C and M Company
P.O. Box 6321
Winston-Salem, NC 27115
Contact: Laura Yarborough
919/723-1838

Appendix C
Plastic Reclamation Recycling Techniques[1]

This section has been included as supplemental information and is not essential to the recycling program designer. But by knowing what happens to plastic recyclables after they have been collected, the importance of planning and promotion of a recycling program will become apparent.

Plastics processors

Plastics processors can be grouped into two basic categories:

- companies reclaiming post-consumer commodity plastic resins to replace, totally or partially, virgin resins in the manufacturing of established consumer products[2] and
- companies reclaiming mixed plastics for new applications that replace materials other than plastics.[3]

Quality in recycled resins

The largest and most profitable market for recycled plastics is for single resins. High quality and purity standards are required to maintain the same product performance characteristics found in virgin material.

Materials processed

Single-resin manufacturers are most interested in HDPE, PET and, more recently, PVC and polystyrene (PS). Presently the most common containers recycled are 2-liter soft drink bottles and 1-gallon milk jugs. However, the market is rapidly expanding to include *all* plastic bottles. In the foreseeable future all plastic containers will be readily marketable as the appropriate technology develops and collection accelerates.

The mixed-resin processors handle a mixture of various resins but require a significant percentage of the mixture to be of a particular resin type, most often polyethylene.

Quality of the feedstock is important for both types of processors. Although single-resin processors have the most stringent quality standards and lowest tolerance for contaminants, mixed-resin processors must also perform quality control sorting techniques to the received feedstocks.

[1] This appendix was written by Sergio F. Firpo, president of Frontier Recycling Systems, Inc.

Typical sorting methods for single resins

In single-resin reclamation, a combination of manual and mechanical sorting techniques is employed.

The basic mechanical separation method uses water density to segregate resins. Plastic resins have a density either greater or slightly less than the density of water. When the value of 1 is given to the density of water, plastics resins with a density greater than 1 will sink in water, while resins with density lower than 1 will float.

A settling tank then becomes a means to mechanically separate two groups of plastic resins, those that float from those that sink. (This is the typical process that easily separates the HDPE base cup material from the PET when soft drink bottles are recycled.)

An apparatus known as a hydrocyclone intensifies this separating effect by means of centrifugal force in a vat of water. In the hydrocyclone, the plastic resins with higher densities exit through the bottom while the resins with lower densities are removed from the top.

With these two methods, it still is not possible to separate all mixtures of resins by density. PVC and PET sink in water and cannot be separated using these methods because their densities are similar.

Plastics resins with density greater than water are: PET, PVC, rigid PS, and polycarbonate (PC), among others. Plastic resins that have a density less than water are: HDPE, LDPE, linear low density polyethylene (LLDPE), PP, and foamed PS.

This classification can be affected by incorporating certain additives to the virgin resin. Color concentrates used as pigment can change the density of the resin in certain cases. For example titanium dioxide (TiO_2), used as a white pigment in HDPE or carbon black used as a black pigment in HDPE, can give it a compounded density greater than 1.

Manual sorting is used primarily to separate easily recognized resins from a mixed stream. It is also used for color separation and to remove bottles that contain too much oil or were used for pesticides and certain household chemicals. Their effect on the end-product is still debatable.

Separation of the different grades of a generic resin can also be performed manually. For example, the typical five-gallon pail and detergent bottle are both made from colored HDPE resin. However, the resin viscosities differ. The five-gallon pail is made by a process known as Injection Molding, and the plastic has a viscosity with a Melt Flow Index (MFI) of 5 or greater. The detergent bottle is made by a process known as Blow Molding and has an MFI of less than 1. The random proportion of these elements in the feedstock will produce a blend of varying properties with limited applications.

Research is being conducted to determine the feasibility of using other resin properties as a means of separation. This will lead to commercial processes for more efficient and effective plastics separation.

The Center for Plastics Recycling Research at Rutgers, The State University of New Jersey, is developing an automatic sorting device that separates five different types from a stream of mixed plastic bottles. Chlorine atoms in PVC reflect light in a specific range of the visible spectrum when illuminated by low-level, X-ray fluorescence. A light sensor sees this reflection, triggers a jetstream of air and kicks the bottles off a conveyor into an appropriate bin. The identification takes place in as little as 1/400 second.

The system also uses LEDs (light-emitting diodes) to identify clear and green PET and natural HDPE. LEDs shine light through the same stream of mixed bottles. Light sensors on the opposite side of the conveyor read the light passing through different resins. These activate airstreams which kick off the bottles at appropriate points. The opaque HDPE is left behind. This technology may permit high quality separation that can eliminate the need for manual sorting.

Also, National Recovery Technologies, Inc., in Nashville, TN, has developed a sorting system that removes vinyl containers from a stream of mixed plastic containers. The sorting system is designed to operate continuously in a rugged environment typical of municipal solid waste processing facilities. This machine is capable of processing mixed plastics containing any level of PVC. The resulting streams have minimal contamination and the system processes bottles at the rate of ten bottles per second.

Reclamation processes

For single-resin reclamation systems with throughput ranges from two to forty million pounds a year, different combinations of the following operations are typically used:

Sorting (as previously described).

Shredding: Reduces the size of the plastic containers to strips from one to three inches in length. This method is a preferred step prior to granulation since it allows for the removal of large hard contaminants that can damage a granulator. An overload circuit stops the shredder when a hardened contaminant jams the shredder thereby preventing any damage to the equipment.

Granulation: Reduces the size of plastic containers or shredded feedstock to particles typically ⅜-inch or smaller. Granulators are designed with rotating and stationary knives to "cut" the plastic. The most efficient models have a tangential feed with blades positioned to produce a scissor-like cut. Capacities range from a few hundred to 5,000 pounds per hour.

Wet granulation: Hot or cold water is added during the granulation process to soften and separate some of the contaminants in and on the containers.

Air classification: Used to separate the light material contaminants, such as paper labels, that become airborne during the shredding or granulation process.

Washing: Granulated material is washed in a tank with hot or cold water with surfactants (detergents) to loosen and remove contaminants (e.g., labels, food, dirt).

Rinsing: With all of the contaminants liberated from the plastic containers, clean water is used to rinse off these contaminants and the detergents used during washing.

Dewatering: Centrifuges and presses are used to remove excess water from the plastic particles to improve the drying process.

Drying: Plastic particles are dried in mechanical and thermal dryers to a final moisture content of less than 0.5 percent by weight.

Electrostatic separation: Aluminum particles from closures as well as other metals are removed by an electrostatic separator. In this process, metal particles are electrically charged and separated in an electric field.

Pelletizing: Clean flakes with a high purity level still have to be extruded and filtered through a screen pack before they can be used in some high-end applications. In this stage, additives can be employed to enhance the properties of the material. A pelletizer at the end of the extruder produces small pellets similar in size to virgin resins. This facilitates the use of the same material-handling and end-product processing equipment as virgin resin.

In addition, some of the following support operations may be performed:

water heating;
chemical additions and controls (i.e., surfactants, polymers, filter aid);
water treatment and effluent controls;
air quality control (dust and odor);
blending and storage silos; and
packaging and shipping.

The water treatment plant is extremely important. The amount of heavy metals (lead, mercury, copper, arsenic, and others), suspended solids, biological oxygen demand (BOD), and chemical oxygen demand (COD) in the water effluent is tightly regulated by local and federal agencies.

Mixed or commingled resins

Mixed-resin processes require less sorting since they are capable of taking a controlled mixture of several resins. In some cases, a minimal percentage of a particular resin is needed to serve as a carrier for the unmelted fraction of the mix. Normally, the mixed fraction is buried inside the product since the more flowable material having the lower melting temperature remains on the outside of the product.

Manual sorting is still necessary to remove certain contaminants (such as metal, glass, and paper) in the feedstock.

Mixed-resin processing, used primarily for producing plastic lumber-like products, includes the following operations: sorting, quality control, granulation, blending, extrusion or molding, and cooling. Cooling is an important step in which the temperature is carefully monitored to prevent warping of the product.

Other mixed-resin processes separate polyethylenes and polypropylenes and produce a pellet with qualities and properties that are dependent on the particular composition of the feedstock. The properties of this blend are typically inferior to those of single-resin processing.

Conclusion

The most promising aspect in the future of plastic reclamation is the recycling of high-quality single-resin type containers. These recycled resins will account for a portion of the market currently being supplied with virgin resin.

Quality of the recycled material is a critical factor in fulfilling the requirements of this market. Until more sophisticated automated separation and processing techniques are in place, the requirements for high quality material will be passed on to the recycling programs supplying the feedstock.

Appendix D
Manufacturers of Household Recycling Containers Made from Recycled Resin

Below is a general list of recycled plastic container manufacturers. The Council for Solid Waste Solutions does not endorse or specifically recommend any company listed.

This list is reprinted with permission from *Recycled Products Guide*, American Recycling Market, Inc., P.O. Box 577, Ogdensburg, NY 13669.

A-1 Products Corporation
P.O. Box 61
Etobicoke, ONT M9C 4V2
Contact: Robin Shea
416/626-6446
10% post-consumer PE

Buckhorn, Inc.
55 W. Techne Center Drive
Milford, OH 45150
Contact: Dave Gherlone
800/543-4454
0-25% post-consumer HDPE
0-25% recovered HDPE

Busch-Coskery of Canada, Inc.
P.O. Box 1626
Mississauga, ONT L4Y 4G3
Contact: Craig Busch
416/762-9672
10% post-consumer PE

Duratech, Inc.
5126 Dorene
Lansing, MI 48917
Contact: Johanna P. Mason
517/321-7712
75-100% post-consumer HDPE

IPL, Inc.
140 Commerciale
St. Damien, PQ G0R 2Y0
Contact: Michel Laganiere
418/789-2880
5-20% post-consumer HDPE

Nucon Corporation
540 Frontage Road
Northfield, IL 60093
Contact: Peter Pigott
312/446-6777
50% post-consumer HDPE
50% recovered HDPE

Plastican, Inc.
196 Industrial Blvd.
Leominster, MA 01453
Contact: Eric Jakobowicz
508/537-4911
15% post-consumer HDPE

Rehrig Pacific Company
4010 East 26th Street
Los Angeles, CA 90023
Contact: Vincent J. Saia
213/262-5145
0-25% post-consumer HDPE

Rubbermaid Commercial Products, Inc.
3124 Valley Avenue
Winchester, VA 22601
Contact: Customer Service
703/665-8244
10-12% post-consumer HDPE

Shamrock Industries, Inc.
834 North 7th Street
Minneapolis, MN 55411
Contact: Mark Smiler
612/332-2100
0-100% post-consumer rubber and plastic

Zarn, Inc.
P.O. Box 1350
Reidsville, NC 27320
Contact: Lee Niegelsky
919/349-3324
5-100% recovered HDPE

Appendix E
Plastics and Related Trade Publications

Canadian Plastics
1450 Don Mills Road
Ontario, Canada M3B 2X7
Subscriptions: Diane Rekoff
416/445-6641
$47.00 per year
published 10 times per year

Chemical Engineering
McGraw-Hill, Inc.
1221 Avenue of the Americas
New York, NY 10020
Subscriptions: customer service
800-257-9402
$29.50 per year
published 18 times per year

Chemical & Engineering News
American Chemical Society
1155 16th St., NW
Washington, DC 20036
Subscriptions: Liz Shirley
202/872-4600
$60.00 per year to non-members
published weekly

Chemical Week
810 Seventh Avenue
New York, NY 10019
Subscriptions: customer service
212/586-3430
$75.00 per year, published weekly.
Includes annual Buyer's Guide

Materials Engineering
Penton Publishing
1100 Superior Ave.
Cleveland, OH 44114
Subscriptions: Jeanice Kennebrew
216/696-7000
$45.00 per year
free to qualified personnel

Modern Plastics
McGraw-Hill Publications Co.
1221 Avenue of the Americas
New York, NY 10020
Subscriptions: customer service
800-257-9402
$38.00 per year
published monthly

Packaging
P.O. Box 173306
Denver, CO 80217
Subscriptions: customer service
800-662-7776
$84.95 per year
published 14 times per year

Packaging Digest
Delta Communications, Inc.
400 N. Michigan Ave., 13th Floor
Chicago, IL 60611
Subscriptions: Kim Aron
312/222-2000
$75.00 per year
free to qualified personnel
published monthly

Plastics Compounding
Edgell Communications
1 East First St.
Duluth, MN 55802
Subscriptions: Priscilla Kruell
218/723-9200
$40.00 per year
published 7 times per year

Plastics Compounding Redbook
Edgell Communications
1 East First St.
Duluth, MN 55802
Subscriptions: Priscilla Kruell
218/723-9200
$40.00 per year
published annually
free with subscription to
Plastics Compounding

Plastics Focus
Plastics Connection, Inc.
P.O. Box 814
Amherst, MA 01004
Subscriptions: Mike Berins
413/549-5020
$229.00 per year
published biweekly

Plastics Design Forum
Edgell Communications
1 East First St.
Duluth, MN 55802
Subscriptions: Sandy Anderson
218/723-9200
$25.00 per year
free to qualified personnel
published bimonthly

Plastics Engineering
Society of Plastics Engineers, Inc.
14 Fairfield Drive
Brookfield Center, CT 06805
Subscriptions: Donna Birch
203/775-0471
$40.00 per year
published monthly

Plastics Machinery & Equipment
Edgell Communications
1 East First St.
Duluth, MN 55802
Subscriptions: Brenda Tefft
218/723-9200
$35.00 per year
published monthly

Plastics News
Crain Communications, Inc.
965 E. Jefferson Ave.
Detroit, MI 48207-9966
Subscriptions: Janet Bagby
313/446-6000
$20 per year
published weekly

Plastics Recycling Update
P.O. Box 10540
Portland, OR 97210
Subscriptions: Barbara Belmore
503/227-1319
$85 per year
published monthly

Plastics Technology
Bill Communications, Inc.
633 Third Ave.
New York, NY 10017
212/986-4800
Subscriptions: Mat Clancy
212/973-4901
$45.00 per year
published annually

Plastics Week
McGraw-Hill, Inc.
1221 Avenue of the Americas
43rd floor
New York, NY 10020
Subscriptions: James Amerson
800/537-9213
$480 per year
published weekly

Plastics World
Cahners Publishing Co.
44 Cook Street
Denver, CO 80206
Subscriptions: customer service
303/388-4511
$69.95 per year
published 13 times per year

TechPak
McGraw-Hill, Inc.
1221 Avenue of the Americas
New York, NY 10020
Subscriptions: James Amerson
800/537-9213
$417 per year
published biweekly

Appendix F
Solid Waste Management Journals

BioCycle
JG Press, Inc.
Box 351
Emmaus, PA 18049
Subscriptions: Shirley Yeakel
(215) 967-4135
$55 per year, $89 for two years
published monthly

Fibre Market News
4012 Bridge Ave.
Cleveland, OH 44113
Subscriptions: Rosalee Slusher
800-456-0707
$95 per year
published weekly

Garbage
435 North Street
Brooklyn, NY 11215
(718) 788-1700
$21 per year
published bimonthly

Plastics Recycling Update
P.O. Box 10540
Portland, OR 97210
Subscriptions: customer service
(503) 227-1319
$85 per year
published monthly

Public Works
Public Works Journal Corp.
Box 688
Ridgewood, NJ 07451
Subscriptions: Helen Brady
(201) 445-5800
$30 per year
published 11 times per year

Recycling Times
1730 Rhode Island Ave., NW
Suite 1000
Washington, DC 20036
Subscriptions: Mike Johnson
202/659-4613
$95 per year
published 26 times per year

Recycling Today
GIE Publishers
4012 Bridge Avenue
Cleveland, OH 44113
Subscriptions: Rosalee Slusher
$32 per year
published monthly

Resource Recycling
P.O. Box 10540
Portland, OR 97210
Subscriptions: customer service
(503) 227-1319
published monthly

Scrap Processing and Recycling
1627 K Street, NW, Suite 700
Washington, DC 20006
Subscriptions: Jackie Tyler
(202) 466-4050
$18 per year

Solid Waste and Power
410 Archibald Street
Kansas City, MO 64111
Subscriptions: Sandy Sexton
(816) 931-1311
$49 per year
published bimonthly

Waste Age
1730 Rhode Island Ave., NW
Suite 1000
Washington, DC 20046
Subscriptions: Mike Johnson
(202) 861-0708
$75 per year
published monthly

Waste Dynamics of New England
500 Commercial Street
Manchester, NH 03101
Subscriptions: Mista Vox
(603) 624-1442
$36 per year
published monthly

Waste Tech News
131 Madison Street
Denver, CO 80206-5427
(303) 394-2905
Subscriptions: customer service
$25 per year
published 24 times per year

World Wastes
6255 Barfield Road
Atlanta, GA 30328
Subscriptions: Lilly Johnson
(404) 256-9800
$40 per year
published monthly

Appendix G
Glossary of Terms

Baler: Equipment that compacts recyclable materials and retains them in compacted form to reduce volume and transportation costs.

Compactor: Equipment that will densify recyclable material and contain it, under pressure, not allowing it to expand until it is unloaded. (See perforator/flattener)

Curbside Collection: Collecting of select recyclable materials from residential curbsides and transporting them to various processing facilities.

Densify: To increase the weight-to-volume ratio of recyclables. Plastic densification equipment includes balers, compactors, and perforator/flatteners.

Drop-Off Center: A central point for collecting recyclable or compostable materials. Materials are taken by individuals to the drop-off center and deposited into designated containers for future transportation to the recycling center.

Handler: An intermediate processing company that buys bottles and containers from communities for recycling. Often a handler accepts presorted recyclables and bales them for shipping to reclaimers.

Hauler: A transporter of recyclable materials from a collection site to a handler or other recycling facility.

Hydrocyclone: A funnel-shaped device that uses centrifugal force in a vat of water to separate resins of different specific gravities.

Integrated Solid Waste Management: The U.S. Environmental Protection Agency recommends a balanced approach to solid waste management through an integrated system that uses source reduction, recycling, waste-to-energy incineration and landfilling to safely and effectively manage the reclamation, reuse or disposal of plastics and other materials in the waste stream.

Landfill: A private or municipal site where municipal and/or industrial solid waste is buried.

Material Recovery Facility (MRF): A facility that processes collected mixed recyclables into individual pure streams for market; also known as an intermediate processing center (IPC).

Perforator/Flattener: Equipment that perforates and flattens material, then ejects the material into a receptacle or processor. Perforators do not hold the material under pressure. This type of equipment helps to prevent plastic bottles from reexpanding after being flattened. (See compactor)

Post-Consumer Material: Any product that has served its initial use including both household and commercial items.

Post-Industrial Material: Industrial manufacturing scrap.

Reclaimer: A company that processes used plastics into granulated flakes or pellets or into new plastic products. Reclaimers are also called Processors.

Recycling: A process by which materials that would otherwise become solid waste are collected, separated or processed and returned to the economic mainstream in the form of raw materials or finished goods.

Reprocessing: The operation of reforming reclaimed materials into new products.

Resource Recovery: Any process that recovers value from the waste stream in the form of material or energy.

Solid Waste: Garbage, refuse, sludge, and other discarded solid materials including those from industrial, commercial, and agricultural operations; private homes; and community organizations.

Solid Waste Management: The systematic administration of activities that provide for the collection, source separation, storage, transportation, transfer, processing, recycling, incineration, treatment and disposal of solid waste.

Source Separation: The segregation of recyclable materials by consumers at the curbside or at a recycling drop-off center.

Tipping Fee: A charge for the unloading or dumping of waste at a recycling facility, composting facility, landfill, transfer station, or waste-to-energy facility, usually stated in dollars-per-ton or dollars-per-cubic yard.

Transfer Station: A location where waste materials are taken from smaller collection vehicles and placed into larger transportation units for more cost-effective movement to market or disposal facilities.

Volume Reduction: The processing of waste materials to decrease the amount of space the materials occupy. Reduction can be accomplished by mechanical, thermal, or biological processes.

Appendix H
Print Resources

Bierce, Rose; Iudicello, Suzanne; and O'hara, Kathryn, J., "A Citizen's Guide to Plastics in the Ocean," Center for Marine Conservation, Washington, DC (1988)

Bottom Line Consulting, Inc., "Guide for Recyclers of Plastics Packaging in Illinois," by Fearncombe, J., Illinois Department of Energy and Natural Resources (November 1990)

City of Columbus, Ohio, Pilot Program for Curbside Recycling, Refuse Division (1988)

Council for Solid Waste Solutions, *Time Magazine* (Special Supplement), "The Urgent Need to Recycle" (July 17, 1989)

Council for Solid Waste Solutions, "The Solid Waste Management Problem. No Single Cause, No Single Solution." A primer on municipal solid waste management (1990)

Curlee, T. Randall, "The Economic Feasibility of Recycling: A Case Study of Plastics Wastes," Praeger (1986)

Environmental Action Foundation, *Legislative Summary: Statewide Recycling Laws*, Solid Waste Alternatives Project (October 1988)

Environmental Defense Fund, Inc., *Coming Full Circle, Successful Recycling Today*, in Cohen, Nevin; Herz, Michael; and Rustin, John, Environmental Information Exchange, New York (1988)

Environmental Law Institute, *Evaluation of Economic Benefits of Resource Conservation* (1978)

Environmental Management Services, *Plastics: From Problem Waste to Potential Resource* (Proceedings from the conference held on August 17 and 18, 1989)

Franklin Associates, Ltd., "Characterization of Municipal Solid Waste in the United States, 1960-2000." Final report prepared for the U.S. Environmental Protection Agency (March 1988)

Franklin Associates, Ltd., "Economic Incentives and Disincentives for Recycling of Municipal Solid Waste" (December 1988)

Franklin Associates, Ltd., "Estimates of the Volume of Municipal Solid Waste and Selected Components" (October 1989)

Illinois Department of Energy and Natural Resources, Energy and Environmental Affairs Division, *Feasibility of Tax Incentives for Purchases of Recycling Equipment or Recycled Products* (May 1987)

Institute for Self-Reliance, *Garbage in Europe: Technologies, Local Economics and Trends* (May 1988)

Institute of Scrap Recycling Industries, "Scrap: America's Ready Resource," *Phoenix Quarterly* (1988)

Michigan Department of Natural Resources, *Options to Overcome Barriers to Recycling*, Resource Recovery Section (February 1987)

Minnesota Project, "Case Studies in Rural Solid Waste Recycling," 2222 Elm Street, SE, Minneapolis, MN (November 1987)

National Association of Towns and Townships, *Why Waste a Second Chance? A Small Town Guide to Recycling,* Brown, Hamilton, et al., National Center for Small Communities (1989)

National Recycling Coalition, "The National Recycling Coalition Measurement Standards and Reporting Guidelines" (draft October 31, 1989)

National Resource Recovery Association, "Garbage Solutions: A Public Official's Guide to Recycling and Alternative Solid Waste Management Technologies," Chertow, Marian, United States Conference of Mayors (1989)

National Solid Waste Management Association (NSWMA), "Public Attitudes Toward Garbage Disposal" (November 1989)

National Solid Waste Management Association, *Recycling Solid Waste* (1988)

New Jersey Office of Recycling, *Some Questions & Answers About Municipal Recycling Ordinances* (1988)

New York State Legislative Commission on Solid Waste Management, *Incentives for Recycling,* Bruno, Joseph L., Senator (January 1988)

The Polystyrene Packaging Council, Inc., "Polystyrene Foam Food Service Products: Environmental Impact and Waste Disposal Components" (1989)

The Polystyrene Packaging Council, Inc., "Polystyrene Packaging and Solid Waste Disposal: Issues and Answers" (1989)

Rathje, W.L., "Comments on S.1112 and S.1113: The Solid Waste Disposal Act." 101 Congress, 1st Session, before the Senate Committee on Environmental and Public Works (1989)

Rhode Island Dept. of Environmental Management, *Guide for Preparing Solid Waste Recycling Plans for Multi-Family Residence Units,* Ocean State Cleanup & Recycling (May 1989)

US Department of Energy, *Model Contract for a Full-Service Resource Recovery Program,* Bernheisel, J.F. (1982)

US Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States, 1960-2000* (March 1988)

US Environmental Protection Agency, *Design of Consumer Containers for Refuse or Disposal,* Sachsel, G. (1972)

US Environmental Protection Agency, *Materials and Energy Recovery from Municipal Solid Waste in the United States,* 5th U.S.-Japan Government Conference on Solid Waste Management (1982)

US Environmental Protection Agency, *The Possibilities & Practicalities of Business Waste Recycling,* Recycling Now

US Environmental Protection Agency, *The Solid Waste Dilemma: An Agenda for Action,* Report EPA/530-SW-89-019 (February 1989)

US Environmental Protection Agency, *Source Separation Study,* Ramsey County Public Health Dept. (1980)

Wirka, J., *Wrapped in Plastics.* An Environmental Action Foundation Report (1988)

Worldwatch Institute, *Mining Urban Wastes: The Potential for Recycling,* Worldwatch Paper 76, Pollock, Cynthia (April 1987)