Reprinted from
RESOURCE RECYCLING
North America's Recycling and Composting Journal
www.resource-recycling.com

Curbside Plastics Collection

Collecting plastic bottles more efficiently

by Ted Siegler

To improve on plastic bottles' 19-percent recycling rate, a dozen curbside recycling collection programs in six project areas were studied. The results are presented here.

The very characteristics that attract packagers and consumers alike to plastic bottles – they do not weigh much and they hold a lot of product – are the same ones that give fits to municipal officials attempting to stretch already thin recycling budgets so they can collect new materials, such as plastic bottles. Despite this, a combination of citizen demands, state landfill restrictions and higher recycling goals have spurred plastics recycling over the past five years.

Today, approximately 19 percent of plastic bottles, or 16 percent of all residential rigid plastic containers, are collected for recycling from approximately 4,000 curbside collection programs. This represents substantial growth in plastic container recycling since 1989, when just over four percent of residential plastic containers were estimated to have been recovered for recycling.

During 1992 and 1993, the American Plastics Council (Washington) sponsored extensive research on plastic bottle recycling in six areas of the U.S. (comprising a dozen recycling programs) in an effort to increase plastics recycling through improvements in collection efficiency. Each of these Model Cities Projects (see sidebar), as they were called by the APC, tested collection equipment and/or approaches, gathered data on how many plastic containers were generated in the waste stream and set out for recycling, and analyzed collection efficiency and costs. Data collection and analysis for each project was managed by a local environmental consulting firm.

Detailed results of all six studies are currently available in separate reports from the APC. In addition, a single collection manual is being developed by the APC using data gathered in the six studies. This article presents an overview of important findings affecting curbside recycling collection efficiency, especially as they relate to the collection of plastic bottles from residential generators.

Model city locations*

- San Francisco
- South Florida
  - Broward County
  - Palm Beach County
- Western Massachusetts
  - Springfield
  - Chicopee
- Research Triangle, North Carolina
  - Cary
  - Chapel Hill
  - Durham
  - Garner
- West Linn, Oregon
- Seattle
  - Mercer Island
  - Point Cities

* This list does not include drop-off recycling programs that were also examined as part of the Model Cities Projects.

Generation and recycling rates

Improving collection efficiency must begin with development of information on how much material is in the waste stream and how much is likely to be captured by a recycling collection program. Although information on national resin production allocated to plastic bottles is available, relying on these data can be misleading, because the distribution of bottles by state or region and the allocation of bottles among residential, commercial and institutional consumers is not specified.

Therefore, one component of the Model Cities Projects was to evaluate household participation and set-out rates, and conduct capture rate analyses to determine how many plastic bottles are actually available in the residential waste stream and what proportion are set out for recycling by a participating household. Data on generation and set out of glass containers and aluminum and steel cans were also collected, which provide a useful addition to the data on these materials that other trade associations, municipalities and private haulers may have developed.

Participation rates were defined as the percent of households on a given route setting out recyclables at least one time during a month. Set-out rates were defined as the per-

Ted Siegler is vice president of DSM Environmental Services, and environmental consulting firm located in Ascutney, Vermont.

centage of households on a given route setting out recyclables on a single collection day. Capture rates were defined as the weight of designated materials recovered, divided by the weight of the total designated materials available. For all of the Model Cities Projects, "available" was defined as the total amount of material placed at the curb for recycling (in the set-out bin or bag) and placed at the curb for disposal (in the trash can or bag) for a collection time period of equal duration.

It is important to note here that the data presented in this article represents averages and that there are variations among regions of the country in the use of plastic bottles and, therefore, in the quantities potentially available for recycling. For example, different areas of the country prefer milk in polycoated paperboard containers, HDPE jugs or returnable glass milk jugs.

Total household generation

Table 1 presents data on total household disposal of plastic bottles and other recyclable containers. The term "disposal" is used because bottles returned for deposit or to a buy-back center were not included in these studies. Data presented in Table 1 is based on sorting all household waste placed at the curb for disposal and recycling from over 1,000 sample households in the six Model Cities Projects. In most cases, disposal rates for a single route are based on a sample of approximately 100 households.

Table 1 presents the data separately for households in states with and without beverage container deposit or redemption systems (hereafter called "bottle bill states" and "non-bottle bill states") because of the impact on aluminum, glass and soda PET bottle discards associated with deposit laws. (For the purpose of this study, California has been included as a bottle bill state, even though the California system differs form the more traditional container deposit systems in place in Oregon and Massachusetts.)

As Table 1 illustrates, household container discards in states with bottle bills average 234 pounds per year of plastic bottles, aluminum and steel cans, and glass containers, either as solid waste or recyclable; in non-bottle bill states, total discards average 285 pounds per year. Due to other packaging variables among the states, the 51-pound difference cannot necessarily be assumed to be containers diverted via the deposit system. Other non-packaging variables, such as the prevalence of buy-back recycling centers, may contribute to this difference as well.

Plastic represents approximately 11 percent, by weight, of 25 pounds per year per household of total recyclable containers in the waste stream in bottle bill states, and 13 percent or 35 pounds per year per household in non-bottle bill states.

■ Table 1 — Recyclable containers potential available per household (1)

	Bottle bill states					Non-bottle bill states				
	MA	OR	CA	Average		WA	NC	FL	Average	
	(pounds per year)				Percent	(pounds per year)				Percent
All plastic bottles	29	30	15	25	10.5	26	37	42	35	12.3
Glass containers	122	183	193	166	70.8	253	180	171	201	70.5
Aluminum cans	2	6	7	5	2.1	20	14	16	17	6
Steel cans	50	42	25	39	16.6	32	NA	NA	32	11.2
Total containers	203	261	239	234	100	330	230	228	285	100

NA = Not applicable
(1) Totals may not add up due to rounding
Source: American Plastics Council, 1994

Composition of the plastic bottle stream

Table 2 illustrates the composition of plastic bottles in the household waste stream. Twenty-two pounds, or approximately 90 percent, of the plastic bottles in the average bottle bill state household waste stream are two resins: PET (3.4 pounds) and HDPE (18.8 pounds). PVC bottles represent, on average, 0.5 pounds per year, or 2.2 percent of plastic bottles.

The remaining resin types (PP, LDPE, PS and other) account for only 0.6 pounds per year, or 2.3 percent, with polypropylene (PP) bottles representing the majority of these other bottles.

The difference between bottle bill and non-bottle bill states is especially significant when the composition of plastic bottles is compared. In non-bottle bill states, soda PET bottles are the largest component of the plastic bottle stream, averaging just over 13 pounds per household per year. Total PET, including custom (non-soda) PET, averages 16.8 pounds per household per year, or 48.5 percent of total plastic bottles. Natural HDPE (primarily milk and juice bottles) and pigmented HDPE (primarily detergent bottles) add another 16.2 pounds per household per year to the plastic bottle stream. Thus, PET and HDPE compose over 95 percent of the plastic bottles discarded from the average household in non-bottle bill states. The other resins make up 2.8

■ Table 2 —Plastic bottles, by type, per household (1)

	Bottle bill states					Non-bottle bill states				
	MA	OR	CA	Average		WA	NC	FL	Average	
	(pounds per year)				Percent	(pounds per year)				Percent
All plastic bottles (2)	29	30	15	25		26	37	42	35	
PET soda	1.4	0.5	1.3	1.1	4.3	8.3	17.7	13.4	13.1	37.9
PET custom	1.6	2.7	2.8	2.4	9.7	3.5	3.1	4.5	3.7	10.6
Total PET	3	3.2	4.1	3.4	14	11.7	20.8	17.8	16.8	48.5
HDPE pigmented	7.5	7.3	3.8	6.2	25.3	3.7	5	4.3	4.3	12.5
HDPE natural	15.9	16.1	5.7	12.6	51.2	8.4	9.4	17.8	11.9	34.3
Total HDPE	23.5	23.3	9.5	18.8	76.4	12.1	14.4	22.1	16.2	46.8
PVC	0.3	0.5	0.9	0.5	2.2	0.5	0.7	0.6	0.6	1.7
LDPE	0	0.1	0.1	0.1	0.3	0.1	0	0	0.1	0.2
Polypropylene	0.1	0.8	0.4	0.4	1.7	0.4	0.6	0.5	0.5	1.4
Other plastic	0.1	0.1	0	0.1	0.3	0.1	0	0.4	0.2	0.4
Uncoded and other	1.6	1.3	0	1	3.9	0.6	3.3	0.2	1.4	3.9

(1) Totals may not add up due to rounding
(2) No polystyrene bottles were found.
Source: American Plastics Council, 1994

pounds per non-bottle bill household, compared to 2.1 pounds in the bottle bill states.

Clearly, the preponderance of PET and HDPE bottles is an important factor to consider during the design of a curbside collection program. For all intents and purposes, there are virtually not LDPE or polystyrene bottles. The small amount of polypropylene bottles in the residential waste may be insignificant when mixed with HDPE bottles, because markets for HDPE are likely to accept the small amount of polypropylene as a relatively benign contaminant.

The decision then becomes whether to include “all plastic bottles” in a collection program, or to specify plastic bottles by resin types. In both cases, there will be some collection of PVC bottles, which are incompatible with PET bottles, even in low concentrations. Inadvertent collection of PVC bottles, which closely resemble custom PET bottles, can be minimized by collecting soda PET bottles only. But using such a collection strategy would eliminate a significant source of relatively valuable custom PET and PVC.

In most cases, higher participation and capture rates for the target bottles will occur if all bottles are accepted.

What are the findings?

- ✔ Households in bottle bill states dispose of an average of 25 pounds per year of plastic containers versus 35 pounds per year in non-bottle bill states.
- ✔ In households in non-bottle bill states, PET and HDPE bottles are generated in nearly equal amounts and represent 95 percent of all plastic bottles.
- ✔ In bottle bill households, over five times more HDPE containers are generated than PET, with HDPE and PET representing 90 percent of all plastic bottles.
- ✔ Recycling programs that accept all plastic bottles can achieve higher participation and capture rates.
- ✔ An on-truck plastics compactor is cost effective in a non-bottle bill state, but may not be in a bottle bill state.
- ✔ Reducing unproductive time and improving sorting and loading activities can increase collection efficiency.
- ✔ Most households store recyclables for almost two weeks before setting them out for collection.

Participation, set-out and capture rates

One of the questions frequently asked about adding plastic bottles to an existing recycling program concerns the impact that adding a high-volume material will have on participation rates and on the set out of materials at the curb. Each of the Model Cities Projects involved adding all-plastic bottles to an existing recycling program. Therefore, a key component of the research was an evaluation of pre- and post-plastic collection participation and set-out rates.

Participation rates. Although participation rates of 80 to 90 percent are often referred to in the recycling literature, before plastics recycling collection was introduced, measured monthly participation rates in five of the six Model Cities Projects averaged 63 percent, ranging from a low of 60 percent to a high of 70 percent.

Adding all-plastic bottles to a recycling program appeared to increase monthly participation in the recycling by an average of 8 percentage points. Post-plastic monthly participation rates average 71 percent and ranged from a low of 65 to a high of 75 percent, when measured approximately six to nine months after plastics recycling collection began.

At least three factors may have played a role in the observed increase in participation creates associated with the addition of plastic bottle collection. First, some households began recycling as a result of adding plastics to the list of recyclables collected. Second, there are substantial publicity about the addition of plastic bottles to each of the recycling

In my opinion . . . Is collection cost per ton all that matters?

If given only the high per-ton costs for plastics recycling collection, a municipal official might find it difficult to justify collecting plastics for recycling when the avoided disposal cost is substantially less. However, at least one important argument can be made for including plastics in a curbside recycling program.

According to the 1992 *Council of State Governments/Tellus Institute Packaging Study* prepared for the Council of State Governments (Lexington, Kentucky) and the U.S. Environmental Protection Agency (Washington), “The lightest-weight package, per unit of delivered end product, is generally the lowest-impact product.” For this reason, it is important to analyze how much of each packaging material is being generated by the average household.

Data was collected in each of the six Model Cities Projects to quantify the delivery of product (e.g., soda, milk) per pound of each packaging material. Dividing the sum of the quantity of product delivered in each type of packaging material by the weight of the empty packaging provides a ratio of product delivered per pound of packaging. The table illustrates that, on average, a pound of the lightest packaging material, plastic, delivers 17.5 times as much product to the household as a pound of glass, the heaviest packaging material.

When recycling collection costs are allocated on a per-household basis, or on the basis of product delivered to the household, costs for each of the packaging materials are similar. Although, per-ton recycling collection costs for glass or steel are significantly less than for plastics or aluminum, (see Table 5), to achieve this, significantly greater quantities of glass and steel must be collected from each household.

For this reason, if a municipality is willing to collect glass, steel and aluminum packaging for recycling, then from the standpoint of the household served by the program, collection of plastic bottles makes economic sense.

Ted Siegler

Per-household and per container recycling collection costs

	Product delivered per pound of packaging (oz.)	Collection cost per container (12 oz. container) (cents)	Collection cost per household per month (cents)
Aluminum	275	1.1	24
Glass	30	1.8	32
Plastics	527	1.7	39
Steel	99	2.1	21

Source: American Plastics Council, 1994.

programs. It is likely that this publicity spurred at least a temporary increase in overall recycling participation by some households. Third, the set-out rate increased due to the introduction of plastic bottles (see below). Thus, some households setting out recyclables less frequently than once a month now set out recyclables during the month and thus were counted as monthly participants.

Set-out rates. Although monthly participation is one important indicator of the success of a curbside recycling collection program, information of the number of households actually setting out recyclables on any given collection day determines the volume of material, and therefore truck capacity, as well as the number of stops that must be made on-route. Normally, either truck capacity or the number of stops is the limiting factor in the design of collection routes.

■ Table 3 — Average measured capture rates for recyclable containers

	Average capture rate (percent of total available)	Bottle-bill states (percent range)	Non-bottle bill states (percent range)
Glass containers	80	77-88	56-93
Steel cans	68	60-88	53 (1)
Aluminum cans	71	69-84	56-85
All plastic bottles	55	39-65	50-66
HDPE natural	70	55-87	70-72
HDPE pigmented	39	21-47	41-56
PET soda	60	37-61	60-75
PET custom	48	27-56	47-61
PVC	39	13-44	51-54
All other plastics	20	10-18	17-39

(1) Steel cans were collected in only two of the non-bottle bill Model Cities Projects, and were not reported separately from aluminum in one of those two projects
Source: American Plastics Council, 1994

It was anticipated that adding all-plastic bottles would increase the number of times per month that a household would set out recyclables, because collecting more materials for recycling means using more room to store them between pickups. Set-out rates were analyzed for 12 separate collection programs within the six Model Cities Projects. Five of the programs involved bi-weekly collection and seven involved weekly collections.

Pre-plastic collection set-out rates were measured in two of the five bi-weekly programs and six of the seven weekly programs. Set-out rates were measured in all 12 programs after plastics collection was initiated. There average increase in set-out rates was 8 percentage points for the weekly programs and 5 percentage pints for the two bi-weekly programs, where both pre- and post-plastics collection rates were measured.

The are two observations that can be made about set-out rates measured in the Model Cities Projects. First, the average post-plastics set-out rate for the five bi-weekly programs was 11-percentage points higher that for the seven weekly programs. The average set-out rate for the five bi-weekly programs was 59 percent, ranging from 43 to 72 percent of all households on the route. The average set-out rate for weekly collection programs was 48 percent, ranging from 22 to 67 percent of all households.

Second, while it was anticipated that adding plastics would fill set-out containers too soon, when a second set-out bin or mesh or plastic bags specifically for plastics were provided to households, in most cases, residents continued to use the single set-out container, which simply increased the frequency of their setouts. Often, if there was more recyclable material than would fit in the collection container, the extra materials were placed

■ Table 4 — Determining truck requirements for weekly collection of recyclable containers (1)

	Quantity of material per stop: Weekly generation (2)	(3)	Capture rate (4)	Weeks of material accumulated	Number of stops: Total households on route	Set-out rate (5)	Truck requirements: Density (6)	Daily route volume (7)	(8)
Glass containers	3.19	3.86	0.80	1.8	1,000	0.48	396	5.6	6.7
Steel cans	0.75	0.62	0.68	1.8	1,000	0.48	128	3.4	2.8
Aluminum cans	0.1	0.33	0.74	1.8	1,000	0.48	50	1.2	4.0
All plastic bottles	0.47	0.68	0.56	1.8	1,000	0.48	33	6.9	10.2
HDPE natural	0.24	0.23	0.70	1.8	1,000	0.48	30	4.8	4.6
HDPE pigmented	0.12	0.08	0.39	1.8	1,000	0.48	40	1	0.7
PET soda	0.02	0.25	0.60	1.8	1,000	0.48	35	0.3	3.7
PET custom	0.05	0.07	0.48	1.8	1,000	0.48	35	0.6	0.8
PVC	0.01	0.01	0.29	1.8	1,000	0.48	35	0.1	0.1
All other plastics	0.03	0.04	0.20	1.8	1,000	0.48	35	0.1	0.2
Total truck volume requirements								17.1	23.8

(1) The daily route volume allocated for each material is determined by multiplying the factors of weekly generation, capture rates, weeks of material accumulated, total households on-route and set-out rate, then dividing that result by the specific material density.
(2) Pounds per household in a bottle-bill state.
(3) Pounds per household in a non-bottle bill state.
(4) Percent of generated material set out for recycling.
(5) Percent of all households setting out recycling containers on any given collection day.
(6) Average pounds per cubic yard observed in the six Model Cities Projects.
(7) Uncompacted cubic yards in a bottle-bill state.
(8) Uncompacted cubic yards in a non-bottle bill state.
Source: American Plastics Council, 1994

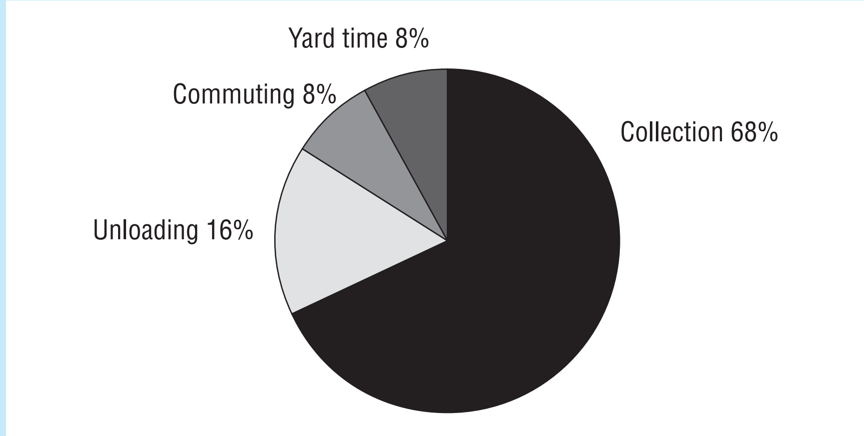
in a paper or plastic grocery bag next to the set-out container.

Capture rates. Not all of the material generated in a household will be set out for recycling collection. To determine capture rates for each type of container, household waste placed at the curb for disposal and recycling was sorted for representative routes within each Model Cities Project. Table 3 presents the range of capture rates observed across the six Model Cities Projects.

As illustrated in Table 3, glass containers showed the highest capture rates, averaging 80 percent. Capture rates for steel and aluminum cans were similar, averaging 68 percent and 71 percent, respectively. Plastic bottles, the "new kid on the block," had the lowest capture rate, averaging 55 percent, but natural HDPE capture rates, at 70 percent, were comparable to those for steel and aluminum.

It was observed during the sorting that containers generated outside of the kitchen area were less likely to be recovered for recycling. It also is important to note that capture rates for the lighter weight aluminum and plastic containers are probably understated because the weight of liquids and food wastes on the sides of these containers when pulled from the trash increased the estimated weight of the non-recycled containers compared to the clean containers set out for recycling. Lighter weight materials are affected more significantly by this contamination factor than are heavier weight materials.

Figure 1 Average values of major workday activities (15 programs)



Source: American Plastics Council, 1994.

Calculating truck requirements

Table 4 illustrates the use of set-out and capture rates to estimate recycling truck requirements. based on a 1,000-household route, assuming weekly collection of glass containers, steel and aluminum cans, all-plastic bottles and some mix of paper (e.g., newspaper and white paper).

Recycling of paper was studied only peripherally in the Model Cities Projects. Paper volumes vary widely, depending on the type of paper collected (e.g., old newspapers vs. old corrugated containers) and demographics (e.g., substantially more old newspapers are generated in Washington, D.C. than in Burington, Vermont). Observations in six Model Cities Projects were that paper occupied approximately two-thirds of a truck's usable capacity in bottle bill states and around one-half of a truck's capacity in non-bottle bill states. For illustrative purposes in Table 4, it is assumed that 10 cubic yards are available for bottles and cans on a standard 30-cubic-yard truck.

In Table 4, weekly generation rates observed in the six Model Cities Projects were divided into averages for bottle bill and non-bottle bill states. These weekly generation rates were multiplied by observed average capture rates for each material and then by the number of weeks of accumulated material set out at the curb by a participating household.

Analyses of the number of times a participating household actually placed its set-out container at the curb for recycling during the month were carried out on weekly routes in three of the Model Cities Projects. On average, 1.8 weeks' worth of material was set out at the curb each time a household placed the set-out container at the curb for collection. This is because for weekly collection programs, an average of only 31 percent of the participating households set out their container every week. Another 23 percent set it out three times per month, 22 percent two times per month, and 24 percent once per month.

Once the amount of recyclable material in the average set-out container has been determined, it can be multiplied by the average number of households on the route setting out recyclables on any given collection day. As previously discussed, the average was 48 percent for weekly programs and 59 percent for bi-weekly programs. Finally, to determine how much volume must be handled by the recycling truck during the day, the pounds of recyclable material can be converted to cubic yards based on average observed uncompacted densities.

As illustrated by Table 4, on a route of 1,000 households, an average of 17.1 cubic yards of uncompacted bottles and cans would be collected in a bottle bill state while 23.8 cubic yards of material would be collected in a non-bottle bill state. The daily route volumes calculated in Table 4 demonstrate three important points.

First, when plastics compactors are not used, all plastic bottles require about 40 percent of the truck capacity devoted to bottles and cans in a bottle bill state, and 43 percent of bottle and can capacity in a non-bottle bill state.

Second, while there are significantly more PET bottles in a non-bottle bill state, there are equally significant increases in glass bottles and aluminum cans.

Third, while a plastics compactor can significantly reduce truck space allocated to plastic in a non-bottle bill state, it is of only marginal value in a bottle bill state. This is because the average 1.0- to 1.5-cubic-yard capacity compactors available on the market occupy between 2.6 and 2.9 cubic yards of truck capacity (based on the outside dimensions of the compactor), saving only about four cubic yards of truck capacity in a bottle bill state, but 7.5 cubic yards of space in a non-bottle bill state.

In the example shown in Table 4, with 10 cubic yards of truck capacity available for all bottles and cans in a bottle bill state, a savings of four cubic yards of capacity would not be enough to avoid a second trip to a processing facility during the day. But because more materials are collected in a non-bottle bill state, a plastics compactor would enable the recycling collection vehicle to avoid going to a processing facility to unload a third time.

Allocating the curbside collection workday

Improving collection efficiency will require improvements in two broad areas of collection time. First, the amount of unproductive time, when the driver and truck are not occupied with actually collecting recyclables, must be minimized. Second, ways must be found to improve the efficiency of collecting (i.e., sorting and loading) recyclables once on-route.

Trucks were followed and timed throughout the entire workday on 15 routes in the Model Cities Projects. The results are consistent and illustrate a key factor in improving collection efficiency. On average, actual collection of recyclables is responsible for only 68 percent of a typical seven-hour day (see Figure 1). The remainder of the day is spent in the yard (8 percent), traveling to and from the route (8 percent) and traveling to and from and unloading material at the material processing facility (16 percent). Thus, an average of 2.5 hours per day are spent on unproductive collection activities, leaving only 4.5 hours for collection of recyclables on-route.

I should be noted here that the workday ranged from a low of 3.7 hours to a high of 10.6 hours across 15 timed routes. When workdays for each route within each Model City were averaged, however, the results consistently fell within an average of seven hours, excluding time spent at lunch and on breaks.

Allocating on-route time. During each of the Model Cities Projects, a significant amount of effort was expended on analyzing on-route collection activities carefully. Collection vehicles were followed on 49 routes throughout the on-route collection day, and all activities were timed.

These activities included distance and travel time between stops, and the amount of time spent on each separate collection activity, including trips to the curb, throws of material, trips to the truck with the set-out container and operation of truck equipment, including plastics compactors. The data was analyzed using ordinary less squares regression analyses; researchers concluded that it is possible to model collection activities.

Differences in data collection and reporting make it difficult to simply present the results. However, data from four of the Model Cities Projects are similar enough so that some generalizations can be drawn that are important to improving collection efficiency. Among them:

- Diving between stops averaged 14 percent of on-route collection time.
- Collecting paper took an average of 27 percent of collection time.
- Collecting bottles and cans took another 22 percent of on-route collection time.
- Getting on and off the truck and walking between the curb and the truck accounted for 37 percent of on-route collection time.
- Using a plastics compactor added between 4 and 10 percent to the on-route collection time.

Important findings from the collection analysis include the following:

First, for routes collecting commingled paper and commingled containers, the average time per stop, including drive time from the last stop, was 44 seconds, ranging from an average low of 30 seconds to an average high of 54 seconds. Thus, if the truck was normally on-route collecting recyclables for 4.5 hours, between 300 and 540 stops could be made. Each additional 10 minutes that can be shaved from off-route or unproductive activities added as many as 15 collection stops. Although it might be convenient to assume that reducing lunch and break time is the key, Figure 1 demonstrates that commuting to the route and driving to and unloading at the processing center are key areas for increasing productive collection time.

Table 5 — Average collection cost per ton by material, in dollars

Model city	Plastic	Aluminum	Steel (1)	Glass	Paper	Average all materials
Bottle-bill states						
Springfield/Chicopee, MA	714	4,048	131	67	34	81
West Linn, OR	795	2,400	400	122	30	103
San Francisco, CA	2,124	1,454	518	106	85	115
Non-bottle bill states						
Seattle, WA	796	526	287	70	68	87
Research Triangle, NC	823	468	(1)	86	39	104
Broward/Palm Beach Counties, FL	557	1,139	(1)	76	45	84
Average cost per ton by material	969	1,673	334	88	50	96

(1) Steel cans were collected in only two of the non-bottle bill Model Cities Projects and were not reported separately from aluminum in one of those two projects.
Source: American Plastics Council, 1994

Second, the average time per stop measured on the one program collecting source-separated material was 59 seconds, showing the additional time required at the curb to individually collect and empty bins for separated materials.

Third, a small fraction of the entire collection day is actually spent physically handling (sorting and dumping) recyclables. Of the 4.5 hours of a seven-hour workday that an average collection vehicle is on-route, a half-hour is spent driving between stops and 1.5 hours is spent getting on an off the truck and walking between the truck and the curbside. This leaves only 2.5 hours out of a seven-hour day for physically handling recyclables. This illustrates the importance of using low-entry, right-side-drive vehicles and designing the route to minimize unproductive truck time, such as turning around, backing down streets, or crossing traffic to pick up recyclables.

Fourth, and most importantly, the small amount of time spent physically collecting materials illustrates the need to reduce the number of households passed by on the route and maximize the amount of material in the set-out container at each stop. Clearly, one way to accomplish this is to collect recyclable materials once every other week. As discussed above, only 31 percent of the households on the average weekly collection route place their recyclables at the curb each week, even after plastics collection was added. In fact, the average set-out bin contains slightly less than two weeks of accumulated material, indicating that the average participating households stores recyclables for just under two weeks.

It can be argued that weekly collection increases participation rates, hence the recovery of recyclable materials. However, observations across the six projects were that other variables, such as neighborhood characteristics, were more important, with some bi-weekly programs recovering greater amounts of material than some weekly programs. Some researchers argue that even if recovery is greater with weekly than bi-weekly collection, this benefit is offset by greater expenditures of resources and increased environmental impact.

Analyzing collection costs

A complete evaluation of the cost-effectiveness of adding plastics to a recycling program requires a comparison of total system costs associated with collecting plastics as solid waste and disposing of them in an incinerator or landfill, and total system costs associated with collecting and processing that same portion of the available plastics through the recycling program. The difference in total system costs would be accounted for by solid waste collection savings associated with removing a high-volume material:

- Avoided disposal costs at a landfill or incinerator
- Lost energy sales revenue if incinerated
- Increased recycling collection and processing costs
- Additional materials sales revenue.

This type of total system cost analysis was beyond the scope of the Model Cities Projects. Instead, the research focused on developing detailed information on the collection component of the recycling system, which is often the largest single cost component.

Allocating costs among materials. Costs for each of the Model Cities Projects were estimated based on fully allocated collection costs. There is no one universally agreed upon method for allocating common costs. For all the Model Cities Projects, costs were generally allocated as follows:

First, the amortized capital cost of collection trucks and equipment was allocated based on the volume of available capacity used by each material. Thus, if all materials were collected loose, then truck costs were allocated based on the uncompacted volume of each material collected. If a plastics compactor was used, then the amortized cost of the compactor and the truck capacity used by the compactor were assigned to plastics.

Second, operating costs were divided into three time components: Sorting and loading; travel and unloading at a materials processing facility; and all other. The three sets of operating costs were then distributed based on the percent of truck and labor time spent on these three areas of activities.

The collection models illustrate that, on average, only 30 percent of the total collection day is spent at the truck sorting and loading bottles and cans and paper. Using the plastics compactor adds another 4 to 10 percent to total collection time. Therefore, this portion of the collection day can be allocated to each material based on the percent of total collection day devoted to sorting and loading this material.

Like equipment cost, delivery and unloading time at the processing center can be allocated among materials based on the volume of each material in the truck, because material volumes determine the number of trips to the processing facility.

The remaining on- and off-route activities are not directly affected by any single material and can therefore be allocated equally among materials. Note that this method of allocation means that the more types of materials added to the collection program, the lower the cost per material, at least until another vehicle has to be bought.

Table 5 presents average fully allocated collection costs, by material, for each of the six Model Cities Projects. As Table 5 illustrates, the results are consistent with costs reported in the literature for various recycling programs around the country. The lightweight materials do not fare well on a per-ton basis. Even aluminum. which is often cited as a valuable recyclable commodity, does not fare well in most cases, especially in bottle-bill states where only small quantities are collected. **RR**