The Monthly UnEconomist

Density and Per Employee Disposal of Commercial Waste In Three King County Cities

I. Introduction and Summary of Findings

During the first half of 2001, Waste Management, Inc. (WMI) companies in King County, Washington used a front-load commercial garbage collection truck fitted with scales to weigh wastes collected from detachable containers for all customers serviced over the course of a five-day route in each of three cities – Renton (weight data collected during January), Kirkland (weight data collected during March), and Redmond (weight data collected during June). This yielded a sample of weights and container sizes on one week of waste for 988 commercial garbage collection customers. Counting multiple collections from customers during the week, as well as multiple containers emptied at a single customer stop, WMI recorded weight data on 1,598 container lifts, an average of 1.6 container lifts per customer over the course of a week.

King County Department of Natural Resources Solid Waste Division provided its database on businesses in King County to Sound Resource Management (SRMG) in order for us to match WMI customer names against that database and extract employee counts and Standard Industrial Classification (SIC) codes for the list of WMI customers.[1] Because business names and addresses in the WMI customer list often did not exactly match names and addresses in the King County database, we had to resort to a time intensive search and match procedure for each of the 988 WMI customers. The result of this merging process for the two lists is a database that has SIC codes for 789 (79.9%) and employee counts for 506 (51.2%) of the 988 customers.

With this information on container sizes, garbage weights, business type codes, and employee counts, SRMG was able to statistically evaluate garbage density variations by container size and business type, as well as garbage disposal per employee by business type and city. The following conclusions emerged from this investigation:

- Garbage density (measured in pounds per cubic yard of collection container capacity) decreases substantially as collection container capacity increases. For example, waste in an eight-yard container weighs about 29% less per yard than waste in a one-yard container, holding constant business type.
- Garbage density varies substantially among business types. For example, waste set out by an eating or drinking establishment weighs on average over twice as much per cubic yard as waste set out by providers of finance, insurance or real estate services, holding constant container size.
- Garbage disposal per employee also varies substantially among business types. For example, retail food stores on average generate over 50% more garbage per employee than do eating & drinking establishments, holding constant container size.
- Garbage disposal per employee varies by city, holding constant business type and container size. Much of this variation may be related to recycling services provided at no additional cost to commercial garbage collection customers – i.e., no-charge recycling may reduce garbage disposal per employee by a significant and apparently substantial amount.

These four findings are discussed in detail in the remainder of this report. Before turning to the detailed analyses, it is worth providing further discussion here regarding the fourth finding, because that finding is likely to be somewhat controversial. The specifics of the fourth finding include the result that businesses located in

[1] The Cities of Kirkland, Redmond, Renton and Olympia each supported a portion of SRMG's time and expenses for creation of the database and for the analyses discussed in this report.

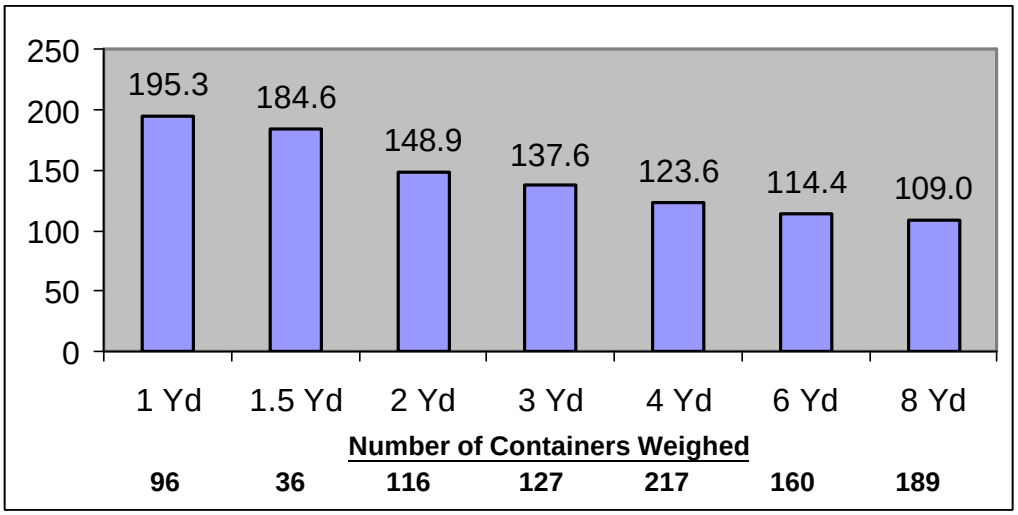
Redmond, where mixed paper, cardboard, cans and bottles recycling is provided at no additional charge to all commercial garbage collection customers that request it, on average generate 28% less garbage per employee than similar businesses in Renton, where commercial garbage collection does not include no-additional-charge recycling. Businesses in Kirkland, where recycling is provided to some businesses on an informal basis at no additional charge, on average generate about 8.5% less garbage per employee than businesses in Renton.

This result for Kirkland is not statistically significant; whereas the result for Redmond is significant at an 89% confidence level. This finding should be considered tentative because our analysis did not control for other factors likely to be important drivers of garbage generation, such as sales per employee or seasonality. Our database on garbage weights also is not large enough to control for business type other than in large groupings such as all manufacturing establishments or all service type businesses. Given the variety of business types included in each broad category, garbage disposal per employee varies so widely within a category that it may obscure differences between categories, as well as making average disposal for a category difficult to interpret. At the same time, one is probably safe in concluding that no-additional-charge recycling services do result in substantial diversion of commercial waste from disposal. But concluding that the diversion impact is definitively 28% may not be justified without bringing additional evidence to bear on the question.

II. Average Garbage Density by Container Size

Figure 1, Average Garbage Density by Collection Container Size, shows the variation in average garbage density according to size of front-load container. As indicated by the bar chart, density declines steadily as container size increases. For example, average density is 195.3 pounds per yard of container capacity for garbage collected from 1-yard containers compared with 109.0 for collections from 8-yard containers, a decline of 86.3 pounds or 44.2%. Average density across all container sizes is 121.3 pounds per yard of container capacity.

Figure 1
Average Garbage Density by Collection Container Size
(pounds per cubic yard of container capacity)



There are several caveats to keep in mind regarding the relationship shown in Figure 1 between average density and container size:

- The data were not gathered on the basis of a random sampling process for container sizes, so average densities by container size shown in Figure 1 may not be representative of average density for each size container in the three cities.
- Average densities shown in Figure 1 are not adjusted for variations in types of businesses using the different size containers. Average densities vary significantly by business type, as discussed in Sections III and IV. Thus, the averages shown in Figure 1 are dependent on the mix of business types on the three routes, and this mix is not necessarily representative of the population of businesses in the three cities.
- The averages shown in Figure 1 are for all collections of a customer's main container size during a week, as well as for all collections of multiple containers of that same main size at a given customer. However, if the customer had more than one container size, the data reflect density for only one of those sizes.[2]

III. Average Garbage Density by Business Type

Figure 2, Average Garbage Density by Business Type, shows variation in average garbage density according to type of business. Business types are shown on the chart ordered from low to high in garbage density. Governmental agencies have the lowest density at 66 pounds per cubic yard of collection container capacity; eating & drinking establishments have the highest density at 221 pounds. As reported in Section II, average density across all container sizes and business types is 121.3 pounds per yard.

As was the case for average density by container size, there are caveats to keep in mind regarding the relationship shown in Figure 2 between average density and business type:

- The data were not gathered on the basis of a random sampling process for business types, so average densities by business type shown in Figure 2 may not be representative of average density for each classification of businesses in the three cities.
- Average densities shown in Figure 2 are not adjusted for variations in types of containers used by the different categories of businesses. Average densities vary significantly by container size, as discussed in Sections II and IV. Thus, the averages shown in Figure 2 are dependent on the mix of container sizes used by businesses on the three routes, and this mix is not necessarily representative of the population of containers in the three cities.
- As indicated by the sample sizes shown in Figure 2, several of the business type categories have small sample sizes that limit confidence in the estimates for their average densities shown in the bar chart.
- As was the case for the averages shown in Figure 1, the average densities shown in Figure 2 also reflect densities for only one size container for those customers that use more than one size of garbage collection container.

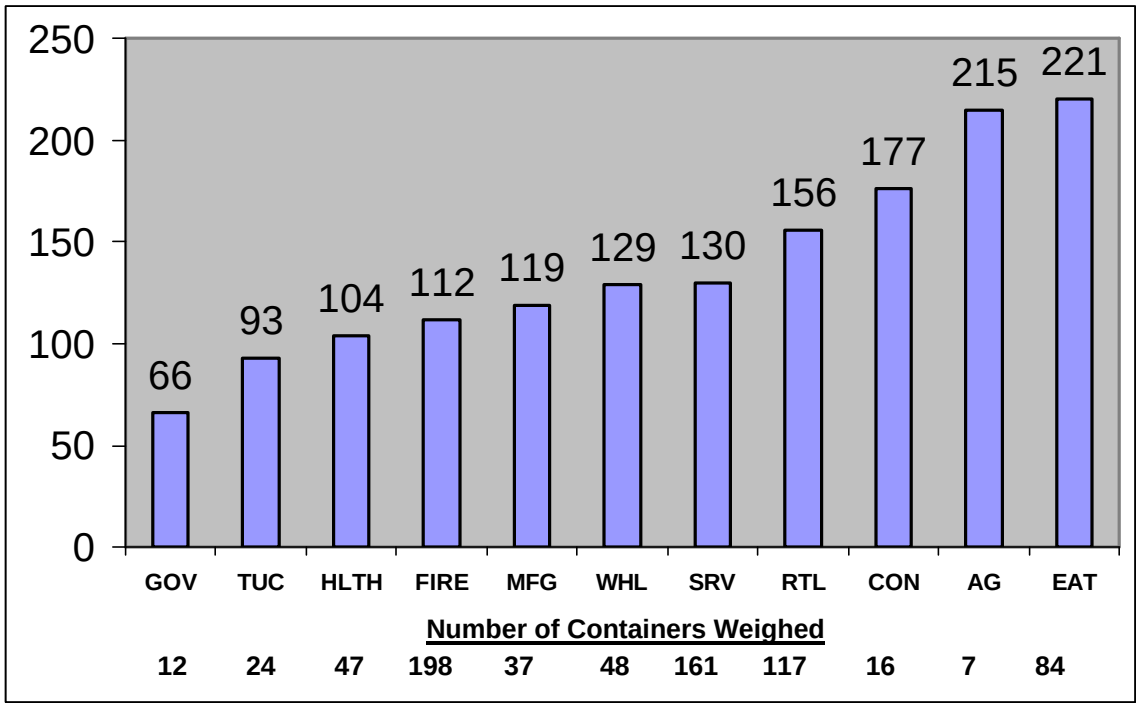
IV. Estimated Garbage Density by Container Size & Business Type

We could obtain accurate estimates of average density for each container size for each category of business types by selecting commercial garbage collection customers using a stratified random sampling process. A stratified sample would require gathering a certain minimum number of garbage weights for every possible combination of container sizes and business types. While a stratified random sample is desir-

[2] The database includes garbage weights for all the different size containers for each customer. However, SRMG's research budget was not sufficient to cover the additional effort required to include weights for more than one container size for each customer in the density analysis. Depending on availability of financial support for additional research, this is an update that could be readily accommodated in future analyses. In contrast, our analysis of garbage disposal per employee is based on weights for garbage in all size containers used by each customer.

able on theoretical statistical grounds, it would impose substantial cost and time burdens on commercial garbage collectors.

Figure 2
Average Garbage Density by Business Type
(pounds per cubic yard of garbage container capacity)



Definition of Business Type Categories:

AG	**= agricultural services**	**CON**	**= construction**
MFG	**= manufacturing**	**TUC**	**= transportation, utilities & communications**
WHL	**= wholesale trade**	**RET**	**= retail trade (except eating & drinking)**
EAT	**= eating & drinking establishments**	**FIRE**	**= finance, insurance & real estate**
SRV	**= services (except health services)**	**HLTH**	**= health services**
GOV	**= public administration**		

Fortunately, there are statistical techniques that we can use to obtain reliable estimates of how density varies with both container size and business type without resorting to stratified random sampling, provided we are willing to make simplifying assumptions. One that is particularly appealing is to assume that variations in density across container sizes are proportionally the same for different categories of business. For example, even though average garbage density for eating establishments is higher than for real estate agencies, average density for eight-yard containers used by eating establishments is assumed to be the same proportional amount below average density for one-yard containers used by eating establishments as it is for eight- versus one-yard containers used by real estate agencies.

Figure 3
Estimated Garbage Density by Business Type & Container Size
(pounds per cubic yard of garbage container capacity)

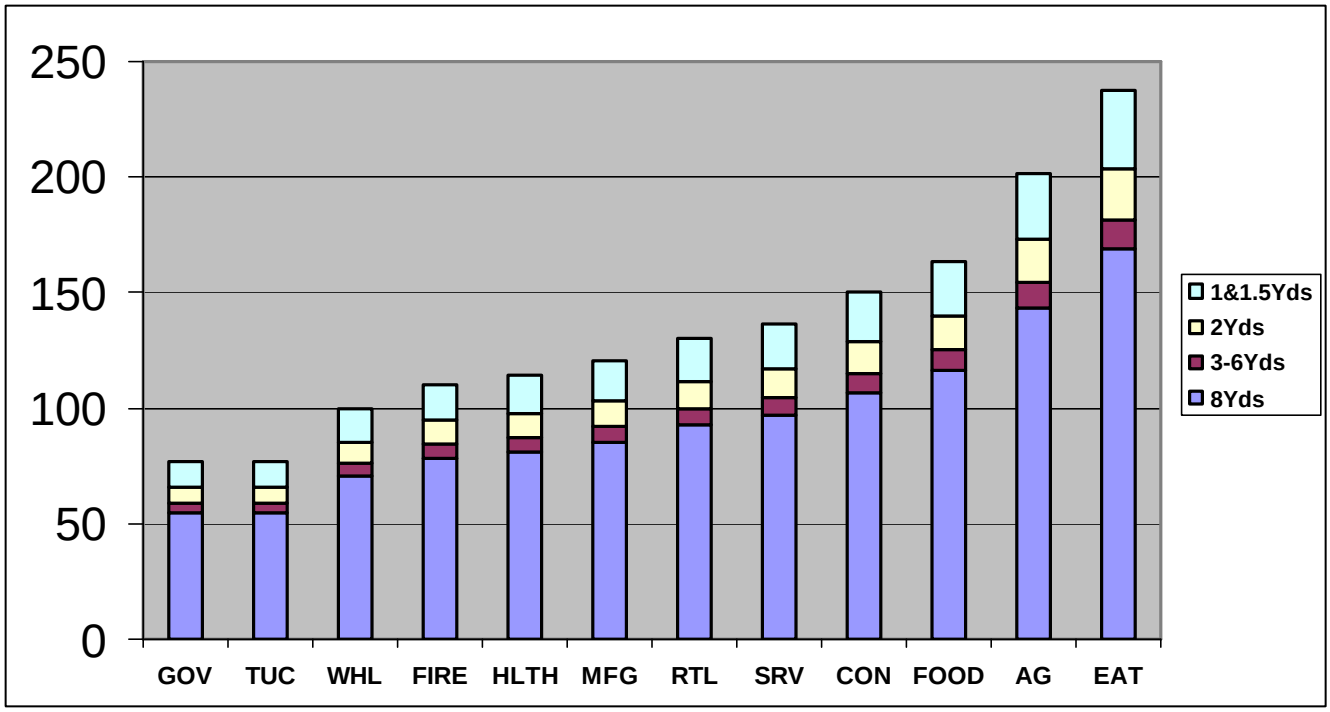


Table 1
Estimated Garbage Density by Business Type & Container Size
(pounds per cubic yard of garbage container capacity)

	8Yds	3-6Yds	2Yds	1&1.5Yds
GOV	55	59	66	77
TUC	55	59	66	77
WHL	71	76	85	99
FIRE	79	85	95	110
HLTH	81	87	98	114
MFG	86	92	103	120
RTL	93	100	112	130
SRV	97	104	117	136
CON	107	115	129	150
FOOD	116	125	140	163
AG	143	154	173	201
EAT	169	182	203	237

Figure 3, Estimated Garbage Density by Business Type & Container Size, shows density by business type and container size that is estimated using log linear regression of observed garbage weight per cubic yard of container capacity on business type and container size, assuming constant proportions for density variation by container size. The business type categories are the same as those shown in Figure 2 and defined in the text box in Section III, except that food stores are reported separately as FOOD in Figure 3. In Figure 3 RTL now means retail establishments excluding retail food stores, in addition to excluding eating and drinking estab-

lishments. Table 1, Estimated Garbage Density by Business Type & Container Size, provides the numeric estimates of density that are portrayed by the stacked bar graph in Figure 3.

The estimates shown in Table 1 and the bar graph are ranked according to density by business category. As one might expect, the rankings in Figure 3 are quite similar to the rankings in Figure 2, with some exceptions. Governmental agencies continue to rank lowest, while eating & drinking establishments rank highest. But transportation, utilities and communications establishments have moved down to equality with governmental agencies, and wholesalers have moved down to third in Figure 3 from their ranking of fifth in Figure 2.

Part of the reason for this change for wholesalers is that in our data wholesalers have a substantially greater proportion of one- through two-yard containers, 47%, than most other business type categories, all but three of which have no more than 30% of the smaller containers. The rankings shown in Figure 2 do not adjust for these variations in container size usage by different types of businesses. So wholesalers rank higher in density than several other business type categories in Figure 2 versus wholesalers' ranking when container size is held constant as in Figure 3 and Table 1. This is an example of how density measurements can be misleading if either container size or business type are ignored.

Separating retail food businesses from the remaining retail business category moves retail below services. Retail food was not shown separately from other retail businesses in Figure 2 because average density for retail food in our data is 155.8 pounds, statistically equivalent to average density of 155.5 for other retail excluding both food and eating/drinking businesses. The fact that container density shown in Figure 3 is significantly[3] higher for retail food versus other retail is the result of both container size distribution and extreme observations. In our data other retail has one customer with a garbage density of 1310, whereas the largest density for retail food is 320. Computation of the simple averages by business category shown in Figure 2 does not exclude outlying observations. On the other hand, log linear regression analysis does tend to moderate the influence of extreme observations. In the case of other retail, log linear regression analysis moderates the influence of the extreme observation, bringing estimated density for other retail down below density for food stores.

Finally, Table 1 does not provide any information about how each business category's garbage density would actually rank relative to any other category in any particular city or county. That computation requires information on the distribution of container sizes within each business category for the particular city or county. Table 1 provides the density estimates to use with a business category's container usage to determine average density for a particular business category in one of the three cities.

V. Estimated Garbage Disposal per Employee by Business Type

Figure 4, Estimated Weekly Garbage Disposal per Employee by Business Type, shows disposal per employee calculated from a log linear regression of garbage weight per employee on business type and container size. The bar graph shows garbage per employee separately for only those business types that had disposal rates that were significantly different. The group with statistically similar disposal rates is shown as OTH in the bar graph with garbage disposal per employee at 37 pounds per week. This all other category in Figure 4 includes agricultural services; construction; transportation, utilities & communications; retail trade (excluding food stores and eating & drinking establishments); and services (including health services).

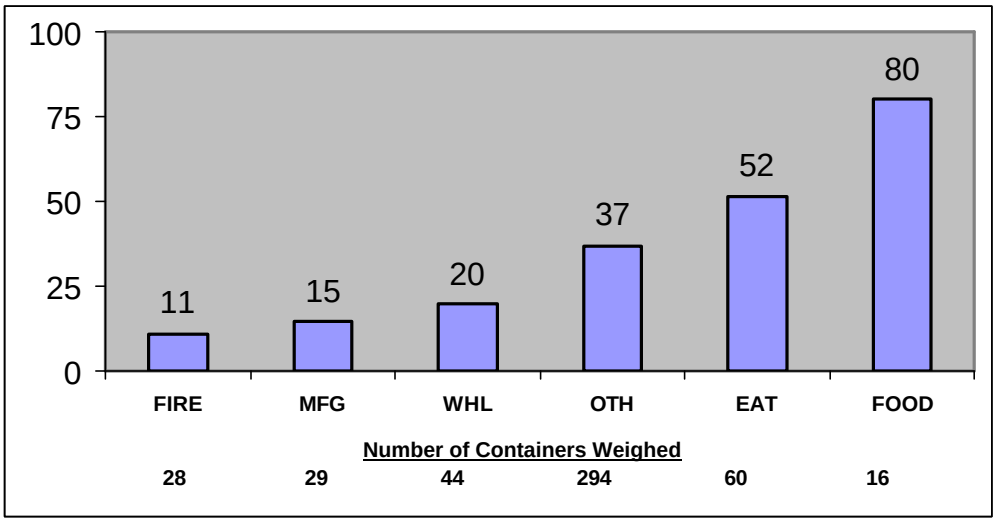
As indicated in Figure 4, finance, insurance & real estate establishments, excluding apartment buildings, have the lowest disposal rate per employee at about 11 pounds a week. Retail

[3] The estimated densities for container size and business type shown in Table 1 are all statistically significant at 99% or above, except for health services at 98%, wholesale at 86%, and the-two-yard container density at 84%.

food stores have the highest disposal rate at 80 pounds per employee. Also, in contrast to their relative ranking for garbage density, food stores have a 54% higher garbage disposal rate per employee than eating/drinking establishments. This is likely due to the restaurant business being more labor intensive than the food store business. Additional labor more than offsets the heavier density of restaurant garbage in terms of the weight of garbage generated per employee.

Governmental agencies are not shown in Figure 4 because we had employment data for only one governmental customer. Apartment buildings also are not shown in Figure 4, but for a different reason. Apartment buildings generate 843 pounds of garbage each week per employee of the building's property manager. Most of this garbage is generated by tenants of the apartment building, not by employees of the apartment building's property management business. Thus, it is not directly comparable with garbage disposal rates per employee for the other business type categories.

Figure 4
Estimated Weekly Garbage Disposal per Employee by Business Type
(pounds per employee)



The regression analysis indicated that only the two-yard container had disposal per employee rates that were statistically different than disposal rates for the other container sizes, holding constant business type. According to the data gathered on the three routes, users of two-yard containers generate over 45% more garbage per employee than users of other container sizes. We have no ready explanation for this result.[4]

VI. Estimated Garbage Disposal per Employee by Business Type and City

Figure 5, Estimated Weekly Garbage Disposal per Employee by Business Type and City, shows disposal per employee calculated from a log linear regression of garbage weight per employee on business type, container size, and city. The stacked bar graph shows garbage per employee separately for only those business types that had disposal rates that were significantly different.

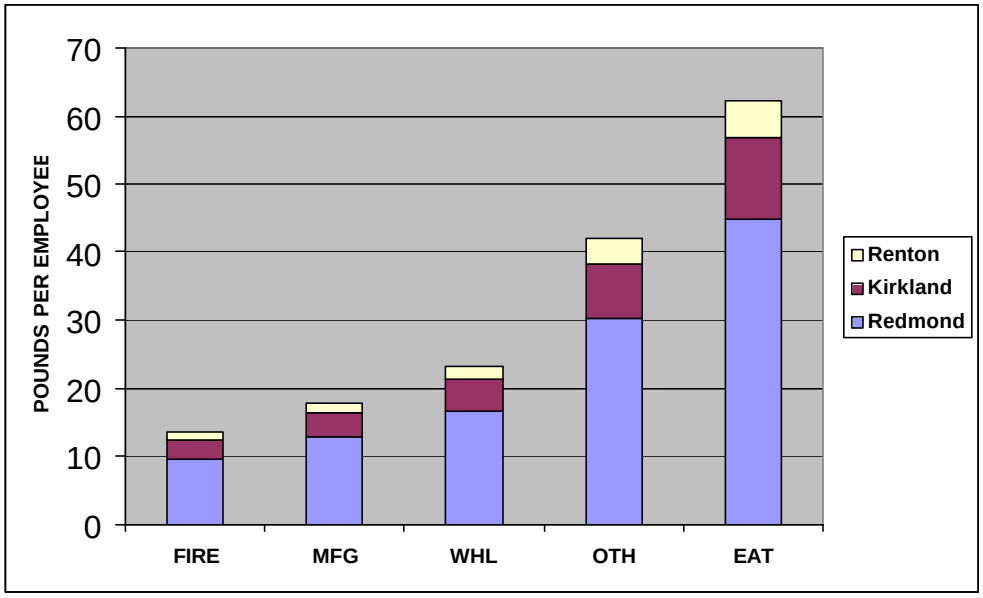
The group with statistically similar disposal rates shown as OTH in Figure 5, with garbage disposal per employee in Renton at 42 pounds per week, for this analysis includes only retail

[4] All results reported in Section V are statistically significant at greater than a 95% confidence level, except for eating/drinking establishments' disposal rate, which is significant at a 93% confidence level.

trade (excluding food stores and eating & drinking) and health services. Agricultural services; construction; transportation, utilities & communications; retail food stores and government are excluded from this particular regression analysis because each of these business type categories had less than five observations on garbage weight per employee in one or more of the three cities. Apartment buildings also are excluded from the analysis because, as explained in Section V, property management firms' garbage generation is more a function of number of apartment units than it is a function of employee count.

Services other than health services were also excluded from the regression analysis used to estimate the data shown in the stacked bar graph in Figure 5. This is because the degree of variability in garbage disposal per employee in the non-health services category is such that inclusion of that category reduces precision for estimates of the city effects. However, rankings of city effects when the non-health services category is included remain as shown in Figure 5 with Redmond having lowest, Kirkland middle, and Renton the highest garbage disposal per employee.

Figure 5
Estimated Weekly Garbage Disposal per Employee by Business Type and City
(pounds per employee)



There may be other explanations for the ranking of the three cities on the basis of per employee disposal rates that is shown in Figure 5 -- such as significant differences in sales per employee among the three cities, or significant differences in garbage generation in the months January, March, and June when commercial garbage was weighed in Renton, Kirkland, and Redmond, respectively. But a very plausible reason is the availability and widespread promotion of no-charge recycling services for commercial garbage collection customers in Redmond. Renton does not provide no-charge commercial recycling, and Kirkland provides it only on an informal, not widely promoted basis. As indicated in Figure 5, we estimate that disposal per employee in Redmond is 28% lower than in Renton, and 21% lower than in Kirkland.[5]

[5] Regression results shown in Figure 5 are all statistically significant at greater then 95% confidence, except for eating/drinking at 91%, Redmond at 89% and Kirkland which is not statistically significant. Container size effects also were not statistically significant at confidence levels of 85% or higher.

About The Monthly UnEconomist

This monthly online newsletter available at www.ZeroWaste.com (or www.SoundResource.com) intends to provide insight and analysis on the everyday economics of recycling and the unpriced or underpriced environmental benefits of reducing waste disposal and replacing virgin-content products with products manufactured from recycled materials. In addition to *The Monthly UnEconomist*, Sound Resource Management's website ZeroWaste.com also offers recycling markets price history graphs, reports on a variety of topics including the economic and environmental benefits of recycling, and GarboMetrics - elegant, yet not mysterious tools and spreadsheet models for solid waste and recycling.

These materials are all available for no charge at www.ZeroWaste.com. User feedback is encouraged via info@ZeroWaste.com, and substantive comments will be published in our newsletter whenever they add to our understanding of recycling.

As an example of newsletter content, some issues of the *UnEconomist* analyze northwestern and northeastern U.S recycling market prices for nine recycled materials (mixed paper, ONP, OCC, glass containers, tin cans, UBC, PET bottles, HDPE natural bottles, and HDPE colored bottles). These prices are tracked by online graphs updated quarterly.

In addition, some issues of the *UnEconomist* are devoted to GarboMetrics, economic models for managing and analyzing solid waste and recycling. These newsletter issues explain the structure and use of GarboMetric models provided at ZeroWaste.com for such purposes as designing garbage customer rate structures and correctly comparing garbage rates in different communities. GarboMetric models and corresponding issues of *The Monthly UnEconomist* can be downloaded at no charge from www.ZeroWaste.com.