THE ORGANIZATION AND EFFICIENCY OF RESIDENTIAL RECYCLING SERVICES

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INTRODUCTION

Residential recycling programs have been established in hundreds of communities in recent years, and many more will be created in the near future. For example, by 1995 every community in the state of Wisconsin is required to demonstrate that it has an "effective" residential recycling program.¹ This in effect requires every community with a population of more than 5000 to provide for the curbside collection of several specified "recyclable" materials² from each household.

In response to such mandates, new market institutions are being created, sometimes almost haphazardly, to collect and process recyclables. This provides economists with an opportunity to observe the rapid evolution of an industry that is certain to play a prominent role in coming years.

Recycling programs differ along several dimensions. Some communities provide dropoff sites for recyclables, some provide curbside collection, and some provide both. Many government entities have established material recovery facilities (MRF's) to sort co-mingled recyclables, while others have hired private-sector firms to provide this service. Collection of recyclables in a few communities is provided by several firms in a free-market setting or by two or more publicly-funded private haulers. In most communities, however, collection is provided as a municipal service or is contracted out to a single private firm.³

The rapid growth of the residential recycling industry has been followed, after a considerable lag, by the emergence of new data on the structure and performance of recycling programs. Thus we can now more easily address some interesting questions concerning the nature of the industry.

This paper focuses on the structure of the market for recycling services. Does the cost of recycling differ significantly between municipal, private-contract, and market-based programs? For reasons discussed below, we expect the private-contract arrangement to be least costly.

The city of Eau Claire, Wisconsin, offers an interesting case study of a market-based recycling program. Households in Eau Claire can buy recycling services from one of several trash-hauling firms, sell their recyclables to a private recycling center, or haul them to one of several rural drop off sites operated by the county. Evidence presented below shows that the costs of recycling services in Eau Claire exceed the costs incurred in most other communities where recycling is organized differently.

The Eau Claire case and preliminary data gathered from a sample of other Wisconsin cities show that significant economies of density can be achieved in communities in which recycling collection is provided by a single firm or agency. The

TABLE 1
Recent Solid Waste Trends

Year	Curbside Recycling Programs	Landfills
1988	1,042	7,924
1989	1,518	7,379
1990	2,711	6,326
1991	3,955	5,812
1992	5,404	5,386
1993	6,678	4,482

Source: Steuteville, 1994.

evidence also suggests that private firms working under city contracts are significantly more cost-effective than municipal collection agencies.

THE RESIDENTIAL RECYCLING INDUSTRY

Regulatory changes at the federal and state levels have brought about sharp changes in the structure of the solid waste industry. The number of communities with curbside recycling has grown, while the number of landfills in operation has fallen. The estimates in Table 1, taken from annual surveys by *BioCycle* magazine [Steuteville, 1994], document these trends.

Solid waste practices vary in a patchwork pattern across the nation, reflecting regulatory differences among states and broader regional differences in disposal and recycling costs. Western states, where population density is lower and open land more abundant, rely more heavily on landfill disposal and less on curbside recycling.

Apotheker [1993] and Stevens [1994] provide more detailed information about the organization of the recycling industry in selected U.S. cities. Apotheker's sample includes the nation's forty largest cities. Of these, sixteen had citywide curbside recycling programs by the end of 1993, and another ten expected to offer citywide curbside service by the end of 1995. As in the aforementioned national surveys, the programs Apotheker describes are remarkably diverse. Apotheker's closer focus on a smaller sample reveals differences in the range of materials collected, collection frequency, average collection costs, and several other program characteristics.

Stevens [1994] considers a random sample of sixty U.S. cities with populations above 25,000. Forty-seven of these cities had curbside recycling programs in early 1994. Twenty-five were private-contract recycling services and twenty-two offered municipal recycling collection.⁴

These surveys did not count dropoff recycling programs, so we cannot measure the relative importance of curbside and dropoff recycling options. Based on Apotheker [1993] and Stevens [1994] we can guess that two-thirds to three-quarters of U.S. cities currently have curbside recycling programs and that about half of these are municipal programs. Among those cities with curbside recycling programs, single-hauler programs are the norm. References to multiple-hauler programs are rare and usually are relegated to footnotes in this literature.⁵

PREVIOUS RESEARCH

Since the study of the economics of recycling is still somewhat new, the academic literature in this area is meager. This paper builds upon earlier work in a related field, the economics of solid waste collection. A series of studies, starting with Savas [1977], have investigated the nature of cost functions in the garbage collection industry. Since the residential recycling industry has a similar setting and technology, the literature on garbage collection provides a starting point for studies of recycling costs.⁶

Dubin and Navarro [1988] is the best recent reference on the provision of garbage collection services and provides a comprehensive summary of earlier work. It characterizes garbage collection with a few stylized facts. First, garbage collection is subject to significant "economies of density"; that is, the average per-household cost of garbage collection tends to be lower in communities with higher population densities.⁷ (This can be used to justify a government role in organizing garbage collection services.) Second, there are no significant economies of scale in garbage collection. Third, a private-contract arrangement in which a community contracts with (or offers a franchise to) a single private-sector service provider is less costly than collection by a municipal agency, which in turn is cheaper than collection by several private-sector haulers. The relative inefficiency of collection by several haulers presumably can be attributed to the presence of economies of density.

The present study is the first extension of this work to the recycling industry. Other aspects of the economics of residential recycling have been addressed in recent research. Duggal, Saltzman, and Williams [1991] and Hong, Adams, and Love [1993] review the relevant literature and estimate the determinants of the volume of recyclables generated by a household and of the household's decision to participate in a recycling program. Dinan [1993] compares the welfare effects of virgin material taxes and a proposed disposal tax and reuse subsidy, and Klein and Robison [1993] estimate solid waste disposal costs for several industries in an input-output setting.

Previous work in this area has evaded a fundamental problem in defining recycling costs. Residential recycling involves several steps: recyclables are separated from the household waste stream, then separated by material type (#1 plastics from #2 plastics, and so on), transported to an intermediate collection point (a dropoff site or transfer site), sold to a broker, sold to a processor, processed, and finally sold as recycled material. The interface between the household and "the market" can come at almost any point in this sequence; the steps preceding this transaction, since they are internal to the household, are generally unobservable. The recycling costs we observe, which usually include only market transactions, thus are difficult to compare across communities unless their recycling programs are similar in scope.

Ideally we would estimate recycling costs in a community by adding to the observable costs an estimate of the household's nonpecuniary recycling costs. Since a household could avoid some or all of these costs by purchasing recycling services or garbage collection services, the nonpecuniary costs might be inferred from an empirical study of the demand for recycling or garbage collection services. Unfortunately, the empirical studies that could support this approach have not yet been done.⁸ Like

earlier work in this area, the present study does not attempt to estimate nonpecuniary costs. The likely scope of any resulting bias is discussed below.

DATA

Each year the Wisconsin Department of Natural Resources (DNR) offers grants to state communities to support their recycling efforts. To qualify for the grants, the communities must complete extensive, detailed applications describing their recycling programs, projecting their costs and tonnages for the coming year, and reporting costs and tonnages for the past year. About 700 communities applied for DNR grants in 1992. In 1993 the number of applicants rose to almost 900, and in 1994 the number exceeded 1000. The present study is based on the 1993 applications, which include actual cost and tonnage figures for 1992. These are the latest data now available.

Most communities report the full range of recycling costs in the application submitted to the DNR, including payments to firms under contract, administrative salaries, processing charges, costs of educational programs, and so on. These costs are itemized in the applications, so (for example) it is possible to net out costs of yard waste collection from other recycling costs. In principle, only cities such as Eau Claire, where a share of residential recycling is arranged through private transactions between households and haulers, do not report their full recycling costs in their DNR applications.

The DNR has supplied a summary of the 1992 data including total costs, yard waste costs, revenue from sale of recyclables, total tons recycled, garbage tonnage, landfill tipping fee, and tonnages of five categories of recyclables collected for each of 868 cities, villages, townships, counties, Indian tribal governments, and recycling commissions.

Since the present study is based on the 1992 cost data, it is important to note their possible limitations. First, local authorities who complete the applications may not have sufficient incentive to strive for accuracy, so the data might be distorted by simple reporting errors.

Second, in their DNR applications communities are applying for subsidies that reimburse all or part of their recycling costs, providing an incentive to inflate their cost figures. Thus, if there is a systematic bias in the cost data, it is likely to be an upward bias. However, the DNR requires municipalities to keep detailed records, and it audits a five-percent random sample each year. One DNR recycling specialist who is familiar with the data said that reporting errors uncovered by the DNR have been few and typically insignificant.

Third, recycling programs vary widely, so cost figures cover different bundles of services in different communities. One program might have collected only newspapers, while another might have collected a wide range of materials. The data does indicate some level of service, but each community's recycling scheme has unobserved idiosyncrasies that might affect its costs.

Finally, in a community that contracts with a private recycling collection firm, the reported costs includes the city's payment to the service provider. If the city contracts with the lowest bidder in an effective competitive bidding process, the payments to the firm may be a good estimate of the firm's costs. But to the extent that recycling haulers are earning positive economic profits, the reported cost data tend to overstate the actual costs of recycling services.

ESTIMATION

For this analysis the sample of municipalities in the DNR data set was narrowed to include just the 57 Wisconsin cities with curbside recycling programs in 1992. Since curbside recycling will soon be the norm in Wisconsin cities, the behavior of this subsample has important implications.

Net recycling costs for each city were calculated by subtracting "ineligible costs" (such as garbage collection costs and the costs of collecting batteries, appliances, or waste oil), yard waste costs, and revenue from sales of recyclables (where applicable) from reported total recycling costs. Revenue from sales of recyclables were subtracted so comparisons could be made between cities that marketed recyclables themselves and those that paid private-sector processing firms to take their recyclables. The total tonnage of recyclables collected in each city in 1992 was used to calculate average tonnage per household.

The DNR data were supplemented by information collected by telephone survey on each city's frequency of curbside collection (times per month) and mode of collection (municipal or private contract) in 1992. Finally, census data provided the number of households and household density (households per square kilometer) in 1990 for each city.⁹

As discussed earlier, in studies of recycling costs unobserved nonpecuniary recycling costs — which of necessity are omitted from the analysis — might be significant, leading to biased estimates. The DNR data do not describe the scope of every city's recycling program, so city programs in this sample could differ significantly. For example, one city might require residents to separate recyclables before placing them at the curbside, while another might collect mixed recyclables; or a city might collect some materials such as corrugated cardboard at a dropoff site rather than at the curbside. In this study the likely scope of the problem is limited by the homogeneity of the sample, which only includes cities with curbside recycling programs.

But differences among service levels doubtless account for some of the unexplained variation in the sample, and it is possible that such differences could bias the results. For example, the results reported below show that municipal recycling services on average cost more than private-contract services. But (for example) if in fact the average level of service was higher (separation by haulers rather than households, perhaps) in cities with municipal service, the present result would reflect a shift of some nonpecuniary costs to observable costs rather than a true cost difference. No evidence of bias of this sort exists in the present study.

The sample is described in Table 2, which gives sample means for the 57 cities with curbside programs and for the 17 cities among them that have municipal collection.

Average (net) recycling costs per household were regressed on several sets of independent variables using ordinary least squares. Results from three alternative specifications are reported in Table 3.

Each specification yields a low R^2 , and the first two fail the F-test, reflecting considerable "noise" in the cost data. The F-statistic in Model 3 is significant at the one percent level. However, in all three models the coefficients on the mode and population density variables are significant and have the expected signs. Thus the DNR cost data suggest that residential recycling costs, like garbage collection costs, are a decreasing function of population density and are higher with municipal collection than with private-contract collection.¹⁰ Population — as measured by the number of households in each city — proved not to be significant in explaining per-household recycling costs in any specifications of the model, so scale economies do not appear to be important in these data. This provides a third parallel between recycling costs and garbage collection costs. It is surprising that collection frequency is not a significant determinant of average collection costs;¹¹ but it is not surprising to see that the dropoff variable is insignificant, since all the cities in this sample have curbside service. Model 2 highlights the importance of the per-household recycling tonnage as an explanatory variable.

EAU CLAIRE'S MARKET-BASED RECYCLING PROGRAM

The city of Eau Claire, Wisconsin, has long supported a fragmented garbage collection industry. Several small haulers have remained independent despite some moves toward consolidation, and the city council has resisted pressure to mandate a single-hauler scheme. When the city established its curbside recycling program at the end of 1991, it mirrored the existing garbage collection market structure. Garbage haulers were granted recycling collection licenses and allowed to make private arrangements with households for curbside collection. Each firm at first attempted to sell its recycling collection service to every household purchasing its garbage collection service, as if the two were a tied good. But only a relatively small share of the city's households chose to purchase curbside collection services. The county had established a number of rural dropoff stations, some of which were located just outside the city limits, and many households chose to take their recyclables there. Other households chose to haul their recyclables to a private recycling collection center within the city limits that paid for aluminum cans and accepted other recyclables.¹²

After some initial confusion and shifts in market share, the city's recycling program settled into an equilibrium in which about one-third of the city's households purchased curbside collection, one-third took recyclables to rural dropoff stations, and the remaining one-third reported that they took their recyclables to the private recycling center.¹³

TABLE 2
Sample Means

Variable	Complete sample (N=57)	Municipal collection (N=17)
Population	26,284	67,252
Housing units	10,591	27,031
Cost per household	\$24.04	\$28.74
Dropoff (YES = 1)	0.53	0.53
Frequency of collection	3.02 per month	2.65 per month
Population density	289.9 households per km ²	225.3
Tons per household	0.17	0.19
Mode (municipal = 1)	0.30	1.00

TABLE 3
LS Regression Results
Dependent Variable: Average Cost Per Household

Variable	Model 1	Model 2	Model 3
Constant	19.03 (3.26)	27.36 (5.37)	20.01 (4.75)
Dropoff	-2.08 (-0.71)	-2.55 (-0.83)	
Collection frequency	0.66 (0.50)	0.43 (0.31)	
Household density	-0.014 (-1.38)	-0.019 (-1.91)	-0.014 (-1.43)
Tons per household	35.9 (2.55)		36.05 (2.61)
Mode	6.76 (2.03)	8.00 (2.31)	6.40 (2.00)
R ²	0.17	0.08	0.19
F-statistic	3.30	2.25	5.39
Sample size = 57			

t-statistics are in parentheses.

Variable definitions: *Dropoff* is a dummy variable; *dropoff* = 1 if the city has a dropoff recycling program. *Collection frequency* is the number of times each household receives curbside recycling collection per month. *Household density* is households per square kilometer in each city. *Tons per household* is reported tonnage of recyclables per household in each city. *Mode* is a dummy variable; *mode* = 1 if the city has municipal collection of recyclables.

Four factors make it difficult to estimate the costs of recycling in Eau Claire. First, the owner of the city's private recycling center has refused to reveal any information about his volumes or costs. Second, while we can observe the prices charged for curbside recycling services by the city's several haulers, these might not accurately reflect their underlying costs. Third, the cost of the city's dropoff recycling service is included in recycling figures reported by the county, but the costs associ-

ated with recycling by city residents are not broken out from dropoff costs for residents elsewhere in the county. Finally, the reported costs of the dropoff program do not include nonpecuniary costs incurred by households (such as time spent driving to the dropoff sites in the city's outskirts), so estimated recycling costs for Eau Claire significantly understate the true cost of recycling.

But the available information allows at least a crude estimate of curbside recycling costs. When the curbside program was introduced in February 1992 five haulers sold weekly curbside collection services for five dollars per household per month. Each hauler also received a subsidy of one dollar per household per month, funded from the same Wisconsin DNR grant program that provided the data discussed earlier. After about one year a sixth hauler entered the industry, offering twice-monthly curbside collection at a price of three dollars per month, and some of the existing haulers started offering monthly or twice-monthly service at prices of two or three dollars per month.

Haulers now charge prices ranging from five dollars per month for weekly collection to two dollars per month for monthly service, with rates uniformly declining with collection frequency. The weighted average of monthly collection rates (using May 1993 quantities as weights) is \$4.36. Market shares and prices have remained essentially stable for the last year. Since entry into the Eau Claire market would be relatively easy, its recent stability suggests that the current price (\$4.36 per household per month plus the one-dollar monthly subsidy) is close to average cost for marginal firms in the industry.¹⁴

One-third of the city's households (or about 7105) reported using the county's rural dropoff program; they constitute 43 percent of the total number of households served by the county's rural dropoff program (about 16,522). The city's share of county recycling costs (\$215,380.89 in 1992) therefore is approximately \$92,620.82. This estimate of the cost of the dropoff program for city residents implies a per-household cost of \$13.04 per year. Ignoring the activities of the unobservable private recycling center (which accounts for the remaining one-third of the city's households), the sum of dropoff costs (\$92,620.82) and curbside costs (7105 households at \$64.32 each) for the city yields a rough estimate of \$549,614.42 for the city's total curbside and dropoff recycling costs, or \$38.68 per household per year. This cost exceeds the reported per-household recycling costs for 50 of the 57 cities in the DNR sample.

Another comparison can be obtained by using the regression results from the last section to predict what Eau Claire's per-household recycling costs would be with a single hauler. The predictions of Model 3 are displayed in Table 4. (The predictions of Models 1 and 2 are similar.) The estimate of \$38.68 per household lies more than one standard error above the point estimate obtained from any of the three models for a private-contract recycling program and almost one standard error above any of the estimates for a municipal program.

Of course, a sample of one observation cannot support meaningful statistical tests. But this evidence strongly suggests that a subscription recycling program with several haulers tends to be more costly than private-contract or municipal programs; indeed, this could account for the fact that market-based recycling programs like Eau Claire's are so rare.

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TABLE 4
Predicted Per-household Recycling Costs: Eau Claire

Private contract	\$22.80
Municipal	\$29.20
Standard error	(10.76)

CONCLUSION

The preliminary evidence presented in this paper suggests that the costs of residential recycling are similar in some respects to the costs of garbage collection, which have been investigated previously by economists. Collection of recyclables appears to be subject to economies of density, but not economies of scale; collection costs are lowest in cities which enter into contracts with single haulers to provide curbside collection.

The estimates of the cost of recycling in Eau Claire, while lacking precision, are consistent with these hypotheses. The several firms providing curbside collection of recyclables in Eau Claire cannot take advantage of economies of density, and their prices exceed the average costs observed in almost all other Wisconsin cities with curbside recycling programs.

NOTES

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1. Wisconsin's recycling requirements, including the criteria defining an "effective" recycling program, are found in Chapter 544 in the state administrative code.
2. In this paper the term "recyclable" is used in the conventional manner without addressing the deeper economic issue of which materials are truly "capable of being recycled."
3. The latter arrangement is the subject of an extensive literature, starting with Demsetz [1968]. Much recent attention has focused on the cable television industry, where Zupan [1989] offers an extensive bibliography of the broader literature.
4. Stevens [1994] also presents data on recycling costs, recycling tonnages, and diversion rates. This is an excellent source of detailed information on the nature of recycling cost functions, particularly with regard to tonnages and diversion rates.
5. For example, Steuteville [1994] notes that there are "subscription programs" — market-based programs like those in Eau Claire — in Utah and Colorado.
6. Residential recycling and residential garbage services have similar technologies at the collection stage. But they differ markedly in subsequent stages. Processing of recyclables is essentially a problem of separation and marketing, while the processing of garbage raises problems of landfill disposal or incineration.

7. Dubin and Navarro [1988] point out that earlier studies failed to find empirical support for economies of density, although they expected it to be important. Dubin and Navarro present evidence of economies of density and explain why it might have escaped earlier investigators.
8. There is a literature on the demand for garbage collection services, of which the best representative is Jenkins [1991]. Jenkins estimated demand functions at the city level, with prices of used newspaper and corrugated cardboard as regressors. In principle such a study could be used to estimate the value of the time and effort devoted to recycling; but these variables proved to be insignificant in Jenkins, so results reported there could be used to calculate only a very crude estimate of the nonpecuniary costs of recycling.
9. Census data are from the 1990 Census of Population and Housing: Population and Housing Unit Counts — Wisconsin.
10. In the sample of 47 cities with curbside recycling programs in Stevens [1994] average recycling collection costs did not differ significantly between cities with private-contract programs and those with municipal programs. Average recycling costs overall were similar to those found here.
11. Stevens [1994, 59-60] expects a positive relation between collection frequency and costs per ton; Apotheke [1993] reports an estimate that Milwaukee could reduce collection costs by 25 percent by reducing collection frequency from weekly to monthly.
12. Households were effectively required to choose some form of recycling, because Eau Claire County prohibited the disposal of "recyclable" materials in the county landfill.
13. Information on residential recycling patterns in Eau Claire is taken from a survey conducted by the Wisconsin DNR in 1992. Households who used the private dropoff center reported recycling habits (in terms of the range of materials recycled) similar to those of households purchasing curbside collection.
14. As in the case of private contract collection, these figures can be used to infer average costs only if firms are earning zero economic profits. There is reason to believe that prices charged by firms in Eau Claire include a significant monopoly markup. The market is highly concentrated, with a Herfindahl-Hirschman Index of 3005. On the other hand, the entrance and rapid growth of a sixth firm in the last year suggests that the market is contestable; and the absence of further entry or price-cutting by existing firms could indicate that prices are not substantially above average costs. An average cost of \$3 per household per month (not counting the \$1 subsidy) would seem to be a reasonable lower bound, since this is the price charged by new entrants for twice-monthly collection. Since most households receive weekly collection, the costs facing their service providers would certainly be higher. An estimate of \$3 per household for curbside service would imply an estimate of \$30.52 rather than \$38.58 per household for Eau Claire's overall recycling costs.

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