I. INTRODUCTION

A. Introduction

Municipalities across the nation are looking toward new forms of residential refuse rates to encourage waste reduction and diversion while bringing in needed revenues. Garbage rates based on the weight of each customer's set-out have been proposed[1] and often have been discussed as a promising solution, but have generally been perceived as functionally impractical. Now it appears the reality of billing by weight is here. A variety of prototype systems are closing in on the goal of accurately weighing and identifying each customer's refuse without interfering with collection patterns. And one system has recently received certification, with several others looking like they are close on the heels! As waste managers continue to debate the benefits of implementing a weighing program, equipment manufacturers are beginning to sell working systems. This study provides highlights of information gathered from weight-based pilot communities and manufacturers in a survey recently completed by Skumatz Economic Research Associates (SERA), of Seattle, Washington.[2]

B. Incentive Systems

Many other forms of variable-rate structures and user-fee systems for residential garbage collection are already becoming popular across the country. The number of solid waste jurisdictions adopting various forms of incentive-based fee systems has been increasing dramatically over the last few years. Cities and towns charging customers for garbage collection based on the amount they generate have increased from barely a few hundred municipalities a few years ago to nearly two thousand currently.[3] Program directors have primarily chosen from a few proven options: 1) variable can subscription systems; 2) pre-paid bag systems; 3) pre-paid sticker or tag systems; or 4) hybrid systems.[4] These are generally called volume-based systems, providing varying rates to customers based on different volumes of waste disposed.

Although volume-based systems provide better incentives than systems that are funded via fixed fees for unlimited collection or through property taxes, volume-based systems have several weaknesses.

- Many systems base fees on subscription rather than usage, with variable can customers paying for a set number of cans weekly, whether or not they use them.
- The systems do not charge less if the containers are not full, so there are no incentives to reduce setouts below filling the smallest container.
- Volume-based systems require rate-setters to translate between tonnage (often the basis of costs) and volume (the basis for revenues), leading to uncertainties, compaction incentives, etc.
- Many volume-based systems (variable can systems) require expensive purchase, delivery, and storage of multiple container sizes.

C. Weight-Based: Improvements to Incentives

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1 Skumatz, “Garbage by the Pound,” *Resource Recycling,* November 1989.

2 This survey was partially funded by the Reason Foundation.

3 Skumatz and Zach, “Community Adoption of Variable Rates: An Update,” *Resource Recycling,* June 1993, and updated surey completed recently by SERA.

4 Skumatz. “Introducing the Hybrid Variable Rate System,” *BioCycle,* November 1993.

Weight-based systems offer customers incentives every week of the year and provide fair, informative billing. They encourage all recycling and reduction efforts, without requiring a variety of refuse containers. Weight based systems can also be expanded to charge different amounts for different materials and waste streams. This enhancement can provide strong incentives to reinforce waste diversion efforts.

Now, many municipalities that have already implemented volume-based systems or are just considering their first pricing are seriously examining a weight-based rate structure as the ultimate solution—and some are wondering whether they should consider skipping directly to a weight-based system.

D. R&D Efforts

Advances are promising for several systems. So far most testing has been at the pilot project level, with varying levels of tests in over a dozen communities. The most noteworthy developments are as follows:

- One semi-automated, scale system has recently received National Institute of Standards and Technology (NIST) certification for implementation in communities. Another semi-automated, in-motion system has passed all the most complicated certification tests.

- Based on our research, several other firms have reached fairly advanced levels of testing and system design and are close to submitting systems for certification.

The early work in a Seattle weight-based fee pilot project demonstrated feasible approaches for weighing and identification[5] and sparked interest from many communities. Since then, much of the research and development work has been funded by scale manufacturers, sometimes with grants or co-funding from communities or indirectly from state agencies. In addition, a government agency in Canada has shown considerable interest and gave funding, on a repayable basis, to a firm to develop and demonstrate a computerized waste-weighing system.

A variety of residential weighing pilot programs over the last four years have produced positive responses from customers and waste managers, and have driven manufacturers to improve prototypes to meet the demands of a fully functioning system.

E. Community Directions and Need

Many municipalities are considering weight-based rates due to some specific drawbacks of volume-based and variable can systems.

- Some communities are considering variable can systems, and wish to provide different size carts at different rates to reward customers for refuse reduction. However, the communities are noting the high expense of this system, including purchasing, maintaining, and distributing a large inventory of different cart sizes (and redistributing containers as subscriptions change). They also note the difficulty of providing an incentive below the smallest cart size (which, for a semi-automated system, is commonly 35 gallons). In addition, a separate bag or tag system is often needed to allow customers to dispose of waste beyond the normal can subscription size.

- Glendale, California, as an example, phased in a variable can rate system over the last few years with semi-automated collection and differently sized program carts. The city views a weighing system as the logical next step and an improvement if the technology were successful. The city

[5] Funded by the Environmental Protection Agency. See, for example, Skumatz, "Garbage by the Pound: The Potential of WeightBased Rates," *Resource Recycling,* July 1991. This test demonstrated the overall feasibility of tbe approach, demonstrated the excellent performance and potential of radio-frequency identification (RFID) tags, and developed and demonstrated a retrofitted semiautomated tipping arm.

believes a weighing system would be simpler for both the city and the residents, requiring fewer cart exchanges.

- Many towns, including Oak Park, Illinois and Montlake, Washington, had already purchased 60- or 90-gallon containers for customers when they moved to semi-automated collection. Now they find themselves in the position of wanting to incorporate variable rates or improve the variable-rate incentives, but cannot afford to purchase new, smaller containers. Other communities recognize that there is a limit to the size of cart that can fit on semi- or fully automated mechanisms. Frequently, cans smaller than 35 gallons must be dumped by hand, reducing the savings from automation.[6]

II. FIELD TEST SUMMARIES

A. Case Studies of Pilot Test Communities

In our study, we found pilot test communities across the country and around the world, including tests in Pennsylvania, New Jersey, North and South Carolina, California, Florida, Minnesota, Washington, and other states, as well as Canada, Australia, Denmark, Germany, Switzerland and other locations. A few of the pilots are summarized below. Further information can be obtained from the authors or from the communities.

1. Seattle, Washington

Seattle conducted the first test of these systems.[7] Seattle conducted a two-phase pilot test in 1989-90 using two systems, with financing from an EPA grant. The first system involved a manual process (bar codes) using available technology to produce data for mock bills and solicit feedback. The second phase tested an early semiautomated tipper scale and radio-frequency (RF) tags, which were successful in identifying carts and weights. Weights were downloaded from a hand-held computer and mock bills were calculated and mailed to customers every other week throughout the experiment. Analysis of the project suggested that customers reduced their setout weights in response to the bills and were supportive of the weighing system concept. Particularly noteworthy was the fact that the study demonstrated that customers reduced the weight of their garbage set-outs by 15 percent, and this is in a community in where a mature volume-based rate system had been in place for eight years! Although weight-based rates are in Seattle's comprehensive plan for the future, Seattle will not be considering any full-scale changes to their collection systems until long-term collection contracts are renewed in 1996 or 1998.

2. Columbia, South Carolina

The pilot program began in the spring of 1994 with 500 households located throughout the City. Data for bills were collected for about 165 households. The system uses a modified semi-automated rear-loader with a 25cubic-yard body. An RFID tag attached to the roll-cart dumper reads the RF tags just below the upper lip of the roll cart. A computer located in the cab of the truck maintains the data. Production (stops collected per hour) during the pilot has kept pace with prepilot rates, and the equipment is submitted for certification.

3. Durham, North Carolina

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[6] And, based on our research, we find widespread in-the-field reports that even 30-35 gallon, semiautomated containers are routinely hand-dumped, bypassing the lifter and associated safety gains.

[7] Skumatz, “Garbage by the Pound: The Potential of Weight-Based Rates.”

Durham began a pilot, weight-based system with 2,800 households in 1992. The system used a semi-automated scale with a poly coder and bar-code scanner. In a six-month field test, the system performed well and proved durable in all sorts of weather extremes. It was then demonstrated in the lab and field for state and federal weights-and-measures officials. In the first set of tests, the scale produced consistent accuracies of 0.1 to 0.3 pounds in level conditions (within the required 0.5 pounds), but the scale did not produce sufficient accuracy at the required 2 to 3 degrees off-level. The manufacturer of this system has since solved this problem. As of spring of 1994, the scale has been certified, but given the time involved, the staff have currently given up trying to get the Council to accept a variable-rate system.

4. Victoria, Capital Regional District, British Columbia

One of the most extensive pilot tests for weighing residential waste took place recently in the Capital Regional District (CRD) of Victoria, B.C. In the CRD municipality of Oak Bay, the collection staff tested prototype equipment to simultaneously weigh and collect three different residential waste streams. In the comprehensive pilot program, the CRD staff worked with a new truck capable of collecting and weighing refuse, nonglass recyclables, and organics in one stop. The truck is an innovative new triple-packer truck with three packing bins and three tipping arms, each of which is modified with load-cell weighing technology and RFID technology. The pilot customers received special carts with RF tags. The system recorded the weight of the contents, the type of material, and the generator and address; this information was then downloaded to computer. This very automated system also downloads the weights *remotely* through a radio system to a computer downtown at headquarters!

The pilot test was made available to all citizens of Oak Bay on a volunteer basis, and 65 percent of the residents opted to participate. Weight-based billing is one of the many diversion incentives that the CRD is examining to push residents toward diversion goals of 50 percent for 1995. Expenses for the pilot test were $325,000, including $100,000 for the new truck. The truck manufacturer provided substantial technical assistance and test carts for below cost. The pilot recently ended and the equipment was removed. The District hopes to implement the system throughout the Capital Regional District in the three- to five-year horizon.

5. Mendham Township, New Jersey[8]

In 1992, Mendham Township implemented a weight-based variable rate system. Rather than charging customers based on the number of pounds, Mendham incorporated a variation that charges customers in 15-pound increments. Customers buy stickers at $1 per 15 pounds and attach the number of stickers needed to “cover” the waste in the container. Although customers need to estimate the number of pounds in a container, the system provides an innovative way around the problems associated with billing and revenue collection (stickers are prepaid). The sticker cost covers the disposal cost of the waste. This system, along with a switch from twiceto once-per-week service and a recycling program, is credited with reducing annual, tax-funded costs per household by about half, increasing recycling by 83 percent, and decreasing disposal tonnage by 55 percent.

6. Milwaukee, Wisconsin

Milwaukee, Wisconsin's pilot test should be in the field in late 1994 or early 1995. Milwaukee's system includes retrofitted semi-automated tippers. Instead of identifying the carts via RFID, Milwaukee is using a computerized routing system in which the routes are read, in order, into the computer, and the computer scrolls the address to the next house at each stop.

7. Farmington, Minnesota

[8] *World Wastes,* February 1993, pp. 36-40.

Farmington wanted to become the first municipality to implement weight-based rates, but because of technological setbacks and ultimately unsuccessful redesigns, the city has ceased working on the system. The city attempted to develop a fully automated collection system, and over the last few years worked with several different companies toward that goal. Occasional field tests were conducted on various combinations of system components with Farmington's modified, fully automated rapid rail collection truck. At least one test operated fairly successfully, except for the electrical problems produced by the abusiveness of field conditions. The static weighing mechanism that Farmington was working on required a two-second pause in tipping cycle. They tested two types of identification and data storage: 1) radio frequency cart identification; and 2) fixed bar-code scanner reading an onboard route sheet. Farmington has experienced retraining difficulties and opposition from collection personnel. At various points, the city has estimated that a fully developed system could cost between $10,000 and $12,000 per truck with an additional $7,000 to $9,000 for office equipment.[9]

8. Minneapolis, Minnesota

Minneapolis ran a small pilot test of a weight-based system in the spring/summer of 1993. They installed load cells on two semi-automated lifters, and used RFID for can identification, read by an antenna. The system weighed before and after dumping, and the information was stored in an onboard computer that was downloaded evenings. They found the system showed good reliability and accuracy, but they did not feel their trial was long enough to determine how well the system would ultimately work. They were concerned that performance would be affected by a wide range of factors, including continuous movement, angle of collection, wind speed, speed of dumping, and relative amounts of refuse. The city, which simultaneously examined alternative, volume-based (variable can) options, is not planning to implement the system at this time. They decided that customers might not like the new system and might complain.

9. Denmark

A fully automated system (with carts similar to 90-gallon) was used in a community in Denmark, charging 2 kroner (35¢) plus tax per kilogram for garbage collection, and recycling collection at no charge. The name and address are attached to the container, and the garbage weighed and recorded by the electronic database in the truck. The community found that people were content with the system. The weighing and recycling programs were reported to have cut by half the amount of garbage having to be burned in the community.

10. Australia

In 1994, a city in Australia conducted a small trial system for residents. Single-family dwelling waste was weighed. The system used computerized identification tags fitted to residents' rubbish bins. The weight of cans and the address of the stop were read as they were emptied into the garbage truck. Residents received regular statements throughout the year informing them of the quantity of their waste, how much they could be expected to charge for that quantity, and how it compared with other set-outs in the community (“mock bills”). Residents also received waste reduction educational materials. The weighing technology developed for the trial was proven not to be accurate over the course of the project and the boundaries of the city changed during the experiment, placing the households outside the confines of the city. For these reasons, they decided not to proceed with implementation of a weight-based program.

B. Manufacturer Survey

We found several firms across the country and internationally that had been involved in one or more components of these systems, with several core firms working successfully on the weighing/scale

[9] The EPA MITE program will be issuing a report describing approaches tried and lessons learned in the Farmington experiment within the next few months.

elements. In addition, prototypes continue to improve, with a number of different groups of companies pooling their expertise in cart-tipping mechanisms, weighing systems, identification technology, and portable data storage in more formal arrangements to develop turnkey systems.

Most preliminary testing of weighing systems has been focused on modifying semiautomated[10] or fully automated cart-tipping mechanisms. These efforts reflect the move by many communities toward curbside semior fully automated systems to increase collection efficiency and decrease costs.

SERA surveyed nearly a dozen firms in the United States and overseas that are actively working on demonstrating or marketing key hardware components to a fully viable "Garbage by the Pound" system. We specifically queried firms on component features, status, field experience, expected costs, and certification issues.

Nearly all scale firms noted being "just about" to submit their equipment for certification, or have already submitted the equipment and passed one or both levels of certification.[11]

Several manufacturers are bringing to market integrated system packages; others are concentrating on a key component and users would need to assemble systems from several firms.

Special features that have been or are being developed include:

- dynamic (in-motion), semi-automated systems;
- automated, sideloader systems;
- radio-downloadable systems;
- weighing in the presence of "shaking";
- autocorrections for inclines;
- long-range, low-frequency ID systems; and
- and other features.

Equipment estimates ranged from about $10,000-$20,000 for scale systems, $800-$2,500 for RFID readers and $3-$10 each for tags.

Table 1

Summary of System Design/Component Options

Scale Options	Read Options	Data Transfer Options	Charge Options
• semi-automated, static • semi-automated, dynamic • fully automated, rapid rail • scales detecting changes in truck weight	• RFID • bar code • bar-coded route sheets • computer scrolls to next address	• downloading, onboard, hand-held computer • radio transfer/download	• calculated bill • prepaid stickers/stamps, in denominated, multi-pound increments

III. EQUIPMENT, CERTIFICATION AND COST ISSUES

[10] Skumatz, "Garbage by the Pound: The Potential of Weight-Based Rates"; see also EPA MITE report.

[11] See description of the certification process under a later heading in this report. Equipment must meet performance standards and tolerances both before and after several weeks of field use.

A. Certification Issues

Our research shows that one considerable obstacle to installing weight-based systems has been developing marketable equipment that would receive certification approval from governmental weights-and-measures agencies. These systems are being asked to conform to Class III level, as defined by the National Institute of Standards and Technology (NIST). This class applies to all scales involved in the sale of goods and services, such as produce and supermarket scales. The requirements are generally equivalent to 0.1-percent accuracy, but depend on the actual increments, division, and capacity of the individual scale. For garbage tippers for residential cans, this would fall between 0.5- and two-pounds accuracy. This requirement has held back implementation of these systems beyond anything but pilot tests.

Some have argued that these requirements are too stringent, noting that: 1) if there is a base fee, all of the charge is not based on weight; 2) the weight does not need to be charged to one-pound accuracy, but could be charged to the nearest two, five, or more pounds (just so long as it is a finer increment than a 32-gallon can); and 3) meters used to charge some other utilities have worse accuracy levels. Some industry representatives lobbied for a switch to a looser certification with accuracies of two to five pounds. However, given that some manufacturers believed they were “close” to developing scales that would meet these standards, the incentive for lobbying decreased because of the unique market advantage that ultimate certification would provide.

One additional barrier was the perception that communities believed they needed to wait for “national” certification before they could proceed. However, federal certification does not necessarily have to be a barrier to implementation of weight-based fees. The decision about whether and when to meet recommended NIST standards is made at the state or local level by weights-and-measures officials. NIST, as an agency, promotes uniformity, and provides “model” sets of regulations, primarily through a publication called “Handbook 44.” This document details recommended tolerances for scales to be used commercially for charges. However, the decision on whether or when to require meeting these standards is made at the *state or local level*—potentially on a community basis (if a community is willing to incur the staffing and training costs). NIST notes that, particularly in New England, townships, cities, and counties commonly have weights-and-measures authority. As one community put it, if the community owns the equipment, they may be able to be quite flexible in their equipment-accuracy requirements. However, for widest marketability, scale manufacturers will likely continue to work toward meeting national standards.

B. Certification Process

Our survey found one firm (Cardinal Systems) has received full certification for a “static” (stop-action) system, and one other firm (Toter) has passed the key phases of certification for a dynamic (in-motion) system. Testing is conducted by National Type Evaluation Program (NTEP) per specifications outlined by NIST.

Certification requires two key phases of testing. As an example of the certification process to meet the first phase of “field permanence tests,” Toter's system needed to meet the accuracy standards by conducting four rounds on each dumper, using 8-10 various configurations of bags and weights ranging from 25-500 pounds, all through the following:

- testing “static” (with stop in cycle)
- testing in motion, on level
- testing in motion, out of level, under four options: Three degrees pitch on each side and three degrees roll both directions (they tested at three degrees and at ten degrees off-level).

Then, after the system passes this first round of “field permanence” tests, it is sealed up and goes into operation for 21 days with no adjustments or tinkering. After this period, it goes through the same round of

tests again to check accuracy to determine whether Class III certification is granted. Toter passed the second round of tests in November 1994.[12]

As mentioned before, one static weighing system, Cardinal Scale's "On Board" Environmental Scale, has received NTEP certification, having passed the designated tests, including accurate out-of-level weighments. This system, requiring retrofitting a semi-automated tipping arm, requires a stop in the cycle to determine the weight. This system slows the cycle time slightly—about 6-10 seconds are added to the normal cycle time—to derive the net weight of the waste in the can. This system is certified for weighment at three degrees or less off-level. At steeper grades, weighing is automatically inhibited. In these cases, communities may need to bill on volume containers or develop other procedures. This 3-degree barrier may not be a problem in many areas of the country (e.g., Southwest, Midwest, Southeast). However, even with across-grade routes, this can be a problem in a number of communities.

Toter's system is an in-motion system for a semi-automated lifting system. The system's cycle time is twelve seconds, and the system passed both rounds of field permanence tests for 10° off-level. This shows promise for a very broad range of communities across the United States and Canada.
No system has yet been certified for fully automated weighing systems (although at least two firms are working on this), nor for the types of systems that have been attempting to weigh differences in the total truck weight before and after dumping the waste.[13]

C. Cost of Equipment and Cost-Effectiveness

At various stages throughout prototyping and pilot testing, the per-truck cost for the equipment has been estimated from $5,000 to $20,000. The survey found ranges of $10,000-$20,000. The system that is currently certified is available for about $12,000 per truck (or $20,000 if two scales are retrofitted on the truck). This cost provides system components including scale, reader, antenna, cabling, and onboard computer. The system would provide downloadable, readable electronic files on name, address, and gross and tare weight.

Depending on the system choice, additional expenses might be incurred for billing and for can identification. Estimates for can identifiers (RF tags) have ranged between $3.00 and $7.50 and $10.00 per can. Bar codes are considerably less expensive.[14] Bar-coded route sheets, scrolling, or sticker systems (e.g., prepaid stickers good for 10-pound increments) would have virtually zero initial cost.

Although the costs may seem off-putting, the system can pay back under very reasonable assumptions in a variety of applications. The examples below assume that new carts cost about $50 each, that RF tags cost $5 each, and that the semiautomated truck can collect about 500-600 (or, in some cases, up to 750) households per day.

1. Savings per Household in Containers

[12] One final check, called the "influence factor" test, requires checking whether the load cell and the electronic components physically function in low, medium, and high temperatures (ranging from +40°C to -10°C). This will be completed by December 1994 and the system will then be fully certified.

[13] However, it should be noted that, although scales that weigh the entire truck should be relatively easily certified (because of the larger range for accuracy), their usefulness for residential can systems seems limited. The error band allowed would generally exceed the weight of average residential cans.

[14] There are, of course, tradeoffs in equipment. Bar codes are cheaper to purchase, but can take longer at the curb, adding to labor expenses. No per-can costs are incurred for systems using bar-coded route sheets, computers that scroll the route, or sticker systems.

If a city with cart-based, semi-automated collection wants to implement a multican, variable can system, they commonly need to purchase new, smaller containers.[15] Assuming new containers cost $50 and RF tags $5, then savings are roughly $45 per household. This excludes the cost of installing identifiers (an additional cost), as well as delivery costs for new containers and redelivery costs as subscriptions change (additional savings).

2. Cost per Household for Truck Retrofit

Apportioning the additional cost of $12,000 per truck among five routes of 500-600 or to 750 per day results in truck and equipment retrofit costs of about $4-$4.80 or less per household, *assuming* costs are attributed in the first year.[16] Lower costs are realized if a twin dumping system is retrofitted or if more households per route can be accommodated.

3. Extra Collections per Week

Changing from manual collection to curbside semi-automated collection can almost double the number of collections per week, from the range of 250-350 up to the range of 400-600 or to 750 per day under semi-automated systems. Because only about half as many trucks and routes are needed, savings are realized in staff and equipment. Additional costs are incurred for new containers and new or retrofitted trucks. If the system is moving from semi-automated collection to a weight-based system, the cycle time is increased, and the route may need perhaps 50 additional minutes to complete if there are 600 homes per route. In-motion systems have shorter delays.

4. Savings per Household in Landfill Fees

Making conservative assumptions, the following savings may help in making “back of the envelope” calculations of costs and benefits. Seattle's experiment found that, even after a mature variable can program, the Garbageby-the-Pound experiment reduced the weight of set-outs by an additional 15 percent per household per week. Assuming a fairly conservative (low) set-out of 30 pounds of waste (perhaps between 35-45 gallons) per household per week, we find that the annual savings in landfill fees would be about $2.35 per household at $20/ton landfill rates; $5.85 per household if landfill tip fees are $50.00/ton; and $11.70 per household if landfill tip fees are $100/ton. This excludes savings from transfer, hauling, and collection routing. Savings would be higher if average set-outs were higher, and lower if the reductions realized were lower.

The previous paragraph provides incremental savings for communities with a *volume-based variable rate incentive already in place.* If a community is moving from flat fees or tax-based funding, even greater savings from the landfill costs could be expected because customers would have an incentive to recycle and reduce that was not previously present. The range in reductions from implementing volume-based variable fees has usually been reported as 25 percent to 60 percent at the landfill or transfer station.[17] Even using a fairly conservative estimate of 7-15 percent additional reduction impact from instituting *any* kind of incentive fees, when we add the weight-based enhancement estimate found in Seattle, we get a total reduction incentive of perhaps 21-30 percent of the weight of weekly household trash set-outs. These revised savings, counting both effects from incentive volume-based fees *plus* the additional weight-based enhancement, would increase from the previous figures to a total between $3.50 and $4.65

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[15] Most communities purchased uniform 90- or 60-gallon containers for all households when they implemented their semi-automated collection systems. However, standard volume-based variable can systems usually need containers for mini- (19-20 gallons), 1-can (30 gallons), 2-can, and other levels. Those households that want to subscribe to can sizes other than those originally purchased would cost the city about $50 per can.

[16] However, capital investments of this sort are commonly paid over a multiyear period.

[17] Skumatz, *Variable Rates for Municipal Solid Waste: Implementation Experience, Economics, and Legislation,* Los Angeles: Reason Foundation, June 1993.

annually per household at $20.00 tip fees; $8.75 and $11.70 for $50.00 tip fees; or $17.50 and $23.40 for $100.00 tip fees. Again, this excludes savings in transfer, hauling, and collection routing. It also excludes impacts on recycling and yard-waste programs. Savings would be higher if starting set-outs were greater than the 30 pounds (35-45 gallons) assumed per household per week.

5. Additional Costs for Billing System

If the community already has a variable can system (or even a flat-fee billed system), the additional billing costs should be fairly minimal as the system provides downloadable readings. However, a new billing system will be needed if the city uses a tax funding method. Depending on the billing system, incremental costs beyond changes needed for a variable can system could be relatively small.[18] Billing costs would be zero under a prepaid sticker/stamp system.

All of the payback cases would tend to improve if the bar-coded route sheet or scrolling systems are used (unless changes in labor time offset equipment savings). Paybacks may be improved yet again under a prepaid sticker system (because no billing system is needed) *unless* incentives are lower without specific weight-based billing feedback. However, it might be argued that the "real time" payments with stickers might provide a stronger incentive than an aggregated bill received at some point in the future.

Community with manual collection willing to move from backyard packout collection to curbside semiautomated collection: The community can roughly halve the number of trucks needed, and staff savings are also realized. Additional costs for the semiautomated systems are about $50.00 per household for containers, plus the billing system. The incremental costs for the weight portion of the system are about $8.00–$9.00 per household. Overall savings at the landfill might range from about $3.50 per household per year to $21.80 per year.

Example Two

[18] For the Seattle pilot test, the author used a 286-PC and standard laser printer to generate bills. However, municipal billing systems often can be inflexible and have high costs involved for changes. Estimates would need to be derived based on the community's system, or from private billing agencies.

Community with volume-based collection with large cans wishing to provide better incenties: The community saves about $45.00 per container and may save anywhere from $2.34 to $11.70 annually per household on landfill fees. Additional costs for the equipment retrofits are about $4.00–$5.00. The net savings would be in the range of $40.00 per household plus landfill savings. If only half the containers need replacing, the total container savings would be about half as much.

Another way of looking at the costs would be to consider the following: If the purchase of new containers could be avoided, at roughly $50 per container, and each truck picked up 600 cans per day for five days per week, the savings would be approximately $150,000. The RF tags cost roughly $5 each, or about $15,000. The range of costs for installing a new "Garbage-by-the-Pound" system is estimated between $5,000 and $20,000 per truck. These figures suggest that payback could be very short for installing a weight-based system.

One community that is considering a weight-based system got an estimate for retrofitting dual flipping arms on five vehicles at a total cost of $405,000 for their 6,000 single-family households. This works out to about $67.50 per household in costs. The incremental cost per household beyond the containers is about $16.00$17.00 per household. The collections are expected to almost double per truck; currently, customers can set out up to five 32-gallon containers, which are dumped by hand. The landfill fees in the community are about $70.00 per ton, showing that significant landfill savings (between $5.85 to $16.40 annually, representing a 1- to 3-year payback) might be expected.

Additional examples can be constructed to meet the considerations associated with particular communities, but the examples show that 1- to 2-year paybacks or even shorter may be demonstrated in some instances, and municipal agencies often work comfortably on much longer timeframes. These systems show promise to be costeffective methods of achieving measurable reductions at the landfill.

Table 2

Illustrative Cost Payback Calculations

		Per household cost and payback at $20/ton tip fee	Per household cost and payback at $50/ton tip fee	Per household cost and payback at $100/ton tip fee
Truck retrofit[a]	household purchase cost possible landfill savings payback	$4.40–$4.80 outlay $2.35/yr. 2 years	$4.40–$4.80 outlay $5.85/yr. < 1 years	$4.40–$4.80 outlay $11.70/yr. < 1 years
Container costs[b]	purchase cost/household	$0–[d]	$0–[d]	$0–[d]
ID[c]	purchase cost/household	$0–$5	$0–$5	$0–$5
Billing	estimated cost/household	$0–[12][e]	$0–[12][e]	$0–[12][e]
Total	total estimated	$4.40–$21.80	$4.40–$21.80	$4.40–$21.80

cost/household	$2.35/yr 2–9 years[f]	$5.85/yr < 1 year–4 year[f]	$11.70/year 1/3 year – <2 years[f]
possible landfill/disposal savings			
estimated total payback			

Note: Assuming semiautomated collection system already in place *or* assuming *incremental* costs for weight-based system when communitv switches from hand-dumped to semi-automated.

[a] Note that with some systems, the collection is slowed by perhaps 10 percent, reducing the payback somewhat.
[b] $0 if existing containers are used.
[c] $0 if prepaid stickers, scrolling computer routing, or bar-coded, in-cab route sheet; assume $5/household for RFID.
[d] $0 because if semiautomated collection is already in place, new containers are rarely needed for weight-based systems.
[e] Billing costs are not well-known. However, we may use cost information from energy utility billing systems that can achieve similar functions as a ballpark estimate. These costs range from $1-$3 per bill/household or $6-$20/customer per year, with bimonthly or quarterly billing.
[f] Note that if billing costs are as high as $12 per year, it would be unlikely to pay back in locations with expected annual landfill saving—in this example, only the highest landfill rate would pay back. Billing frequency could be reduced to save costs.

IV. SUMMARY AND CONCLUSIONS

After initial industry scoffing at the idea, weight-based systems have been extensively tested, and are now certified and are imminently in the field. Groups of companies have established working relationships, with each providing its area of expertise—scales, ID, wiring, computers, etc.—and are putting systems in place. A number of approaches have been tried or are being developed. These include (but are not limited to):

- ***Weighing:*** retrofitting semiautomated tippers with and without stops in the dumping cycle; retrofitted, fully automated tipping arm; mechanisms to detect changes in total truck weight.

- ***Identification:*** bar codes on cans; RFID on cans with antennas on trucks; bar-coded route sheet in cab moved automatically or physically; computer scrolling automatically to next stop on route.

- ***Data storage and transfer:*** hand-held computers; in-cab computers; electronic downloading nightly; remote downloading through radio.

Research, innovation, and refinement continue on all aspects of these systems, and new approaches are being developed. Research and development will continue in the field to develop systems that will work with a range of trucks and collection systems. Semi-automated systems are ready; fully automated appear to need further work. The systems can be cost-effective under a wide range of circumstances.

Only a couple of systems have gone as far as to link the weights with bills or mock bills back to the customer (e.g., Seattle; Australia; Columbia, South Carolina). However, the results have been promising, apparently demonstrating a potent incentive to reduce set-outs.

Sometimes, it takes time for community or decision-maker opinion (or comfort levels) with new ideas like this to catch up. In one community in Virginia, the idea was proposed a couple of years ago, and the community came out adamantly against the idea. Now, the community has taken a 360-degree turn and is asking for the system.

In conclusion, these systems have gone beyond showing promise—they are in the field. Significant progress has been achieved from the first trial pioneering the idea in the late 1980s to street-ready, certified equipment by 1994. The systems are proven and we believe they are likely to lead to widespread adoption over the next decade. Certainly manufacturers echoed that sentiment; one noted that once certification is achieved, the market should “take off” because of the concept's obvious advantages. For

communities without any rate incentive, or even for those with volume-based systems that want to improve the incentives delivered to customers, weightbased systems have many winning features, including:

- efficiency in collection, with no need to hand-dump small containers;
- flexibility to reflect savings for week-to-week variations in set-outs for customers;
- showing customers what they are paying for;
- generalizable to additional waste streams with differing prices, etc.;
- savings from automation in collection, data processing, and billing; and
- continuous incentives for source reduction, recycling, and diversion at all service levels.

Systems are now available and work continues to develop turnkey systems; to improve speed, reliability, and cost; and to develop fully automated systems. It looks as though, after a fairly fast R&D period, the future is now!

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