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Is Municipal Solid Waste Recycling Economically Efficient?

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Abstract It has traditionally been argued that recycling municipal solid waste (MSW) is usually not economically viable and that only when externalities, long-term dynamic considerations, and/or the entire product life cycle are taken into account, recycling becomes worthwhile from a social point of view. This article explores the results of a wide study conducted in Israel in the years 2000–2004. Our results reveal that recycling is optimal more often than usually claimed, even when externality considerations are ignored.

The study is unique in the tools it uses to explore the efficiency of recycling: a computer-based simulation applied to an extensive database. We developed a simulation for assessing the costs of handling and treating MSW under different waste-management systems and used this simulation to explore possible cost reductions obtained by designating some of the waste (otherwise sent to landfill) to recycling. We ran the simulation on data from 79 municipalities in Israel that produce over 60% of MSW in Israel. For each municipality, we were able to arrive at an optimal method of waste management and compare the costs associated with 100% landfilling to the costs born by the municipality when some of the waste is recycled. Our results indicate that for 51% of the municipalities, it would be efficient to adopt recycling, even without accounting for externality costs. We found that by adopting recycling, municipalities would be able to reduce direct costs by an average of 11%.

Through interviews conducted with representatives of municipalities, we were also able to identify obstacles to the utilization of recycling, answering in part the question of why actual recycling levels in Israel are lower than our model predicts they should be.

Keywords Municipal solid waste (MSW) · Recycling · Landfill · Economic analysis

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In 1998, ~90% of household waste in Israel was disposed to landfills. That year, due to a serious crisis at landfill sites and a predicted shortage of land for waste burial from the year 2010 onward, recycling regulations were issued. These regulations required municipalities to recycle part of their waste. A graduated chart was introduced, whereby the minimum rate of recycling increases each year, so that by 2007, all municipalities will be obligated to recycle at least 25% of household waste. The regulations include an exemption section that enables a municipality to refrain from recycling if the municipality is able to show that recycling is not profitable in its case. In response to the publication of the regulations, most municipalities claimed that recycling was not profitable for them and therefore requested exemptions. Because the question is empirical in nature, we examine the economic feasibility of recycling by analyzing data from a large number of municipalities in Israel. The present study, conducted between 2000 and 2004, utilizes data from 79 municipalities in Israel (~30% of all municipalities) whose waste accounts for over 60% of household waste in Israel.

It should be noted that although many types of waste can be recycled, the empirical data available for the purpose of this study concern only some of the recyclable waste components: plastic, paper, cardboard, and glass. These components comprise ~40% of all solid waste in Israel. It should be stressed that other types of waste, such as organic waste and tree trims, are recyclable as well. If these are included in the calculation, ~85% of all solid waste is recyclable. However, due to lack of data, these types of waste are not dealt with in the present study.

The article begins with a review of the literature on the feasibility of waste recycling. Next, we explain our methodology to determine the economic feasibility of recycling in municipalities. We then present an empirical analysis of waste management in the studied municipalities and discuss the results of this analysis. We end with conclusions and recommendations.

Literature Review

In economic literature, the direct costs of recycling are usually considered to be slightly higher than the costs of landfill disposal. However, when externalities are considered, recycling has been found to be economically efficient. For example, Brisson (1997) developed a model in which the optimal amount of recycling is that which brings the marginal cost of recycling to an equal level with the marginal cost of landfill disposal. Huhtala (1997) presented a dynamic model and tested it with data from Finland; the results show that a target of 50% recycling might be justified in terms of an economic and environmental optimum. Ready and Ready (1995) presented a dynamic model according to which the price of landfill disposal increases from the time a new landfill is opened until it is filled, then decreases slightly as a new landfill is opened, and then begins rising once again, due to the problem of land scarcity. Therefore, it is economical to start recycling some of the waste before the price of landfill disposal reaches that of recycling, in order to reduce the costs of landfill over time. Highfill and McAsey (1997) developed a theoretical model for a municipality that has a landfill site with finite capacity and two alternatives for waste disposal: landfilling and recycling. They showed that if the capacity of the landfill is taken into account, it might be efficient for a municipality to recycle some of its waste, even though recycling is more expensive in terms of ongoing costs. In fact, the model showed that the cost calculation should also include dynamic considerations over time, not only the costs of present treatment, so that anticipated future costs are also taken into account. In these studies, the authors examined only the last stage of the waste-management problem (i.e., the stage that begins when waste is placed in general containers); they ignored the process through which waste is produced. These studies all assumed that the costs of recycling are fixed and given and cannot be reduced by other factors at earlier stages of the product life cycle.

Other researchers have dealt with the need to separate waste for recycling at earlier stages; they focused on households as the dominant factor that should bear responsibility for determining how to treat municipal waste (Ayalon and others, 1999; Collins and others, 2006; Harder and others, 2006; Hong and Adams, 1993; Jenkins and others, 2003; Peretz and others, 2005; Van-Houtven and Morris, 1999). Households decide which products to purchase and whether the waste will be separated and placed in special recycling containers or disposed of at the mixed-garbage container. These studies focus on a single incentive method: charging households a volume-based collection/disposal fee for waste removed to the landfill. According to this method, households are not required to pay for removal of separated waste that is sent to recycling. These studies show that imposing "taxation on waste by volume" would lead to economic optimization of the system. A study conducted between 1990 and 1992 (Miranda and others, 1994) surveyed 21 states throughout the United States that had implemented recycling programs. Their findings showed that charging households directly would make the waste-disposal system much more efficient and increase the amount of waste recycled.

Theoretically, these methods seem effective, but they encounter numerous difficulties on the practical level. In particular, Fullerton and Kinnaman (1996) and Jenkins (1993) both noted an increase in illegal waste disposal, pollution of public spaces, and rising administrative and enforcement costs. In addition, the taxation method used was found to be usually regressive. Jenkins (1993) noted that if we ignore illegal disposal of waste, charging for landfilling might lead to achievement of an economic optimum; however, if costs associated with illegal waste disposal are taken into account, the overall cost to the economy might be higher than the benefit and will certainly not lead to an optimal economic solution. Fullerton and Kinnaman (1996) presented a theoretical model as well as empirical results that corroborated Jenkins' claim: Charging households by volume of waste increases illegal disposal, at a very high cost to the economy.

Palatnik and others (2005) examined the use of economic incentives in the field of municipal waste management, specifically those concerning recycling. They found that with low levels of effort needed to participate in a curbside recycling program, household participation rates are mainly influenced by economic variables and age. Harder and others (2006) also examined the factors that influence participation rates. They collected data from over 1400 households in the United Kingdom and found that the number of types of material collected and the number of households situated on the same road are both correlated to participation rates (the former positively, the latter negatively). Collins and others (2006) found a high correlation between income and household participation. Peretz and others (2005) also found that more convenient recycling programs and higher income lead to higher recycling rates. Jenkins and others (2003) found that access to curbside recycling has a significant positive effect on recycling percentages.

Other studies discussed possibilities for governmental intervention at earlier stages of waste production (Eichner and Pethig, 2001; Fullerton and Kinnaman, 1996; Kohn, 1995; Palmer and Walls, 1997; Sigman, 1995). These studies analyzed legislation and regulations that placed responsibility for waste recycling on producers.

One of the most significant pieces of legislation in this area was the "Green Dot" enacted in Germany in 1991 (and implemented beginning 1993). The law placed responsibility for recycling packages on product manufacturers, requiring that they collect and recycle 70% of the packages sold. Manufacturers signed contracts with municipalities and private organizations to collect the packages. Within 1 year (in 1994), the manufacturers (through a collection company—DSD) had met the targets of the law and reached the required return and recycling rates. However, the cost of recycling was extremely high; the average cost of treating a ton of recycled packaging was DM 720, whereas the cost of landfill disposal of the same amount of waste at that time was only DM 211 (Ackerman, 1997). Even taking externalities into account, the cost was higher than the benefit.

Following the German legislation, a European packaging directive was issued in 1994. As a result, many countries (Austria, France, Belgium, Poland, and Argentina) began enacting laws based on similar principles. In light of this, many researchers began examining methods for intervention at earlier stages of the product life cycle, comparing different alternatives. The focus thus shifted to producers of virgin raw materials and product manufacturers.

In all of the aforementioned studies, the deposit method—charging a tax on products and providing the same amount as a subsidy for recycled raw materials—is considered optimal. This policy achieves the result of requiring consumers to pay the full costs of treating the created waste, without creating a problem of illegal waste disposal.

In most of the aforementioned studies, recycling is presented as the more expensive alternative (compared to landfilling) and economically efficient only if aspects such as lack of space for landfill, scarcity of virgin raw material, life cycle analysis, or other externalities are taken into account. This is perhaps due to the fact that in most of these studies, it was assumed that the costs associated with the municipal-collection segment of waste management (the segment preceding the transport of waste from the transfer station to the landfill, consisting mainly of placing and maintaining waste containers, collecting the waste, and transporting it to the transfer station) are fixed. They do not discuss the possibility of saving on costs at the municipal-collection segment by means of recycling. It is important to note, however, that in the United States, the costs associated with the municipal-collection segment account for more than two-thirds of the overall costs of waste disposal (Ackerman 1997, p. 79).

Other studies have looked more closely at the issue of potential savings obtained by recycling. Morris (1993) assumed that when waste is transferred from landfill disposal to recycling, percentage savings in landfill disposal costs equal the percentage of waste transferred. However, according to Ackerman (1997, p. 80), if the municipality does not change its waste-collection system, no savings will be achieved at the municipal-collection segment. Savings then will only occur in the segment outside of the municipality (i.e., the segment starting at the transfer station and ending with burial at the landfill site), which accounts for just one-third of total costs.

Staudt (1993) claimed that the high cost of recycling waste by the DSD in Germany arose from the failure of the municipalities to use the reduction in waste volume achieved by recycling to reduce the number of garbage-removal rounds. According to the study, collection rounds could be cut in half, thereby saving almost half the costs in the municipal-collection segment.

A few studies have examined methods that influence the efficiency of recycling in the municipal-collection segment. Teixeira and others (2004) developed a heuristic model that aims to minimize the operational costs of recycling by improving the vehicle collection routes. Dijkgraaf and Gradus (2003) discussed the possibility of obtaining cost savings by contracting out waste collection; they found potential cost reductions in the Netherlands to be in the range of 15–20%. Dobos and Richter (2003) investigated recycling systems. They found that a mixed strategy of recycling and landfilling could be optimal and reduce total waste-handling costs.

Folz (1999) investigated data on municipal recycling in the United States in 1989 and 1996. He discovered lower average unit costs for cities with higher volumes of waste recycled, implying the existence of economies of scale in waste recycling. Furthermore, the study suggests that if recycling is performed efficiently, recycling costs might actually be lower than traditional waste-disposal costs.

In a more recent study, Folz (2004) dealt with achieving efficient recycling through a benchmarking process. The process consists of a municipality first choosing the quality of service (including the level of recycling) it wishes to provide and is willing to support financially (according to the preferences of its residents), then finding best-fit benchmarking partners and identifying best practices, and finally adopting such practices in order to achieve its targeted level of service quality at minimum costs.

Callan and Thomas (2001) studied the cost structure of municipal solid waste (MSW) management. They claimed that by investigating the relationship between landfilling and recycling, a municipality could create an optimal cost model that combines both landfilling and recycling, thus reducing its waste-management costs. They found that by an optimal combination of recycling and landfilling, a municipality would be able to save $\sim$5%. These savings should then be added to cost savings gained by reducing landfill disposal.

Like Callan and Thomas (2001) and Folz (2004), this article examines the potential savings to municipalities that could be achieved by adoption of an optimal level of recycling. The tools we use to approach the subject, however, are different: This study makes use of a computer-based simulation applied to an extensive database. With extensive data available for each of the municipalities, we were able to arrive at an optimal operational waste-management method for each municipality and estimate the difference in costs between 100% landfilling and a system that combines both landfilling and recycling. We also identified obstacles that limit the utilization of recycling and discovered municipality characteristics that indicate when recycling would be profitable.

The cost evaluation performed for each of the municipalities in our database shows that the option of recycling is efficient for most municipalities, even if we do not take into account additional benefits gained by reduction of externality costs and/or the value of land scarcity. Average cost savings for municipalities stand at 11% of total waste-management costs. However, in order to enjoy the economic benefits of recycling, municipalities must alter their waste-management systems.

Waste Management System in Israel

We begin with a description of the Israeli system of waste management. Curbside garbage containers for mixed waste are situated next to each residential building (the number of containers per building depending on the number of flats in the building, with single-household houses usually also having their own garbage containers). Garbage from these containers is collected and disposed to landfills. Recycled waste, on the other hand, is collected in central containers that are located in a few central locations within the municipality. Thus, households need to bring the waste designated for recycling to these specific locations. The number of recycling containers and the distance between these containers depends on population density and the policy of the municipality. These parameters (among others) determine the level and the cost of recycling.

Development of the Normative Model and the Method of Analysis

The dilemma faced by the municipality is whether to send all of its MSW to landfills or to separate some of the waste and recycle it. In the second case, the municipality will split its MSW into two separate streams—general mixed waste and recyclable waste—as shown in Figure 1.

In this chapter we present the methodology used to construct the model and analyze its empirical implications. First, we present the method of data collection, then the method of analysis, and finally, the results of the analysis and our interpretation of them.

Data Collection

A detailed questionnaire on waste management (Lavee Economic Consulting 2000, see the Appendix) was sent to all municipalities in Israel (a total of 268). We received 142 responses. In addition, we used data from a number of different sources: the Statistical Abstract of Israel 2004 (published by the Central Bureau of Statistics), the Union of Local Authorities' Report of 2004, the Ministry of Interior—development plans submitted by municipalities as well as data from the Population Administration 2004—and the Ministry of Finance-Taxation Division Report of 2004. Finally, we interviewed representatives of municipalities' sanitation and finance departments.

After removing from our database municipalities that did not provide any data or provided data that significantly contradicted other data sources, we were left with data for 79 municipalities.

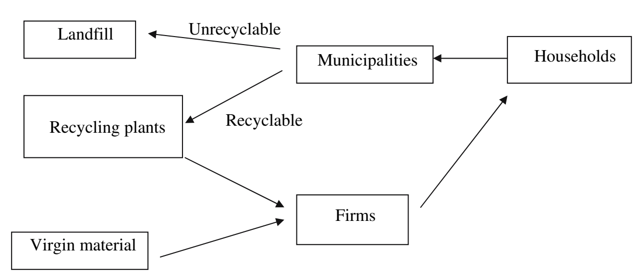

Fig. 1 MSW streams

Table 1 Recyclable waste components as percent of MSW, by volume and by weight

Type of waste	Percentage of total MSW, measured by weight	Volume/ weight ratio	Percentage of total MSW, measured by volume
Mixed waste	100.00%	7.0	100.00%
Type of recyclable waste			
White paper	1.78%	12.0	3.05%
Newspaper and other paper	12.38%	7.5	13.26%
Cardboard	8.21%	16.0	18.77%
PET plastic	1.91%	30.0	8.19%
Other plastic	11.94%	17.0	29.00%
Glass	3.30%	4.5	2.12%
Total recyclable waste	39.52%		74.39%
Remaining waste	60.48%	3.0	25.61%

Method of Analysis

Determining the Components of Waste to be Recycled

In order for a municipality to benefit from recycling, it must recycle a number of waste components so that the quantity of waste sent to landfill is significantly reduced. Therefore, it is necessary to look at the "average waste bundle" of recyclable waste components. The relative weight of each component in the bundle is determined by its actual (physical) weight. Our analysis of recycling feasibility was performed for the bundle.

The following types of waste were examined: paper of different types (white paper, newspaper and other paper), cardboard, glass, PET (polyethylene terephthalate) plastic and other plastic [mainly HDPT (high-density polyethylene)].

In order to determine the relative portion of each type of waste in the bundle, it is necessary to differentiate between two methods of measurement: by weight and by volume (Biotech Environmental 1995).

As can be seen in Table 1, there is a significant difference in the estimated potential for recycling (as percentage of total MSW) depending on whether waste is measured by weight (39.52%) or by volume (74.39%). This difference is extremely important for potential cost reduction in MSW management. We will address this issue later in the article.

Regardless of how waste is measured, this theoretical potential is, of course, not obtainable; in order to reach this level, 100% of each recyclable waste component needs to be recycled, clearly an impossible target. We therefore needed to determine the maximal attainable level of recycling.

Determining the Maximal Attainable Level of Recycling

Even when a municipality provides recycling containers for some of the recyclable waste components, curbside garbage collection for mixed waste is needed for the remaining waste that is sent to the landfill. Therefore, a municipality that is interested in recycling some of the waste will provide recycling containers as well as mixed-waste containers. Every individual can dispose of waste into either container. Therefore, it is necessary to assess what percentage of the recyclable waste will actually be recycled.

From the responses to our questionnaire, we found out that the level of recycling (measured as percentage of total recyclable waste) ranges from about 10% to 80%. In order to understand this dramatic variation between municipalities, we examined three factors:

1. Distribution of recycling containers: the number of containers per resident, the distance between houses and the containers, the dispersal of the containers throughout the municipality.
2. Mixed- waste containers: container capacity and the location of mixed-waste containers relative to that of recycling containers. In most municipalities, curbside garbage containers for mixed waste are situated next to each residential building or house, but in some of the regional municipalities (rural municipal authorities comprised of a number of small communities), only central containers are available.
3. Municipality activities aimed at promoting recycling: publicity and educational activities.

Analysis of the differences between municipalities in terms of recycling levels indicates that these differences can generally be traced to two main factors:

1. Convenience of access to recycling containers
2. Information: residents' awareness regarding the need to recycle and the fact that their municipality engages in waste recycling

Following Folz (2004), we sorted the municipalities by the quality of their recycling services (as measured by the

Table 2 Maximal attainable level of recycling of recyclable waste components, by weight and by volume

Type of recyclable waste	Percentage of total MSW, by weight	Percentage of total MSW, by volume
White paper	1.25%	2.14%
Newspaper and other paper	8.67%	9.28%
Cardboard	5.75%	13.14%
PET plastic	1.34%	5.73%
Other plastic	8.36%	20.30%
Glass	2.31%	1.48%
All recyclable waste components	27.66% = (70% × 39.52%)	52.07% = (70% × 74.39%)

above two parameters) and performed a benchmarking process. We found that for those municipalities that offered the highest level of recycling services, the average level of recycling stood at ~70% (out of the total amount of each type of recyclable waste). In other words, the results reveal that when the municipality works effectively, it is able to achieve a maximum of 70% recycling. Only a small number of municipalities surpassed this target (the leading municipality achieved a level of 80%), but these municipalities have a unique characteristic—a high level of income—so the average municipality (with lower average household income) cannot be expected to reach this same level. We compared these rates to the recycling rates of bottles to which a deposit-refund program applies. These bottles are also recycled at a rate of about 70%.

We concluded then that this is the maximal attainable target in Israel, where none of the municipalities have a volume-based collection/disposal fee on waste. For the purpose of our analysis, we assume, therefore, that the maximal attainable level of recycling is, on average, 70% of the total amount of recyclable waste of each type (see Table 2).

Estimation of the Prices Paid for Recyclable Waste at the Gate of the Recycling Plant

We begin by estimating the prices paid by recycling plants for recyclable waste. In order to determine the average price of recyclable waste (measured in New Israeli Shekel (NIS) per ton), we must first estimate the price paid for each waste component separately (P_{Ri}) (paper, plastic, etc.) and then calculate the price of the bundle (P_R). The calculation is based on the average price of each component in recent years, assuming that this provides a good estimate of anticipated future prices. In order to determine average prices, we performed the following steps:

1. We looked at actual prices paid for the different components in recent years. For this purpose, we conducted a survey of recycling firms in Israel in January 2003. We examined all 12 companies that take waste for recycling in Israel (responsible for 95% of waste recycling in Israel). We compared the data with that obtained from the responses to our questionnaire.
2. We analyzed the contracts between the plants and the municipalities. Some of the contracts are long term (between 5 and 10 years) so that the prices for recyclable waste are fixed, and we can simply use these prices in our calculations. In other cases, we analyzed price changes over the past years.
3. We analyzed changes in world prices. Because recycling plants in Israel export most of their output, world prices heavily affect the prices these plants are willing to pay for recyclable waste.

After determining the average price of each component of recyclable waste, we calculated the weighted average price of the entire bundle, using the relative weights of the recyclable components comprising the bundle (see column 2 of Table 3). The average price of the bundle is thus given by

$$P_R = \sum \frac{\alpha_i}{\beta} P_{Ri}, \tag{1}$$

where P_R is the weighted average price of the bundle, α_i is the percentage of the ith component out of total waste, and β is the percentage of all recyclable components out of the total waste.

The results of our analysis regarding the prices paid for recyclable waste, by component, are presented in Table 3.

Estimation of the Costs of Handling Recyclable Waste (Separation, Collection, and Transport of Recyclable Waste to the Recycling Plant)

In Israel, recyclable waste is collected by private contractors. The contractor charges an annual lump sum for maintaining the recycling containers and collecting and transporting the waste to the recycling plant. The annual

Table 3 Estimate of prices paid by recycling plants for recyclable waste

Type of recyclable waste	Price paid for recyclable waste (NIS per ton)	Percentage of each component out of total recyclable waste (%)
White paper	292.5	4.50
Newspaper and other paper	56.0	31.33
Cardboard	100.0	20.77
PET plastic	600.0	4.83
Other plastic	200.0	30.21
Glass	73.0	8.35
Average recyclable waste bundle	147.0	100.00

Table 4 Estimated cost of handling recyclable waste

Type of recyclable waste	Cost of handling, C_{Ri} (NIS per ton)	Percentage of each component out of total recyclable waste (%)
White paper	290	4.50
Newspaper and other paper	243	31.33
Cardboard	160	20.77
PET plastic	800	4.83
Other plastic	500	30.21
Glass	220	8.35
Average recyclable waste bundle	331	100.00%

payment depends on parameters such as frequency of removals, container volume, and type of recyclable waste, but it is unrelated to the amount of waste in the container (at any given point in time); effectively, the contractor will charge the same amount whether a container is full of waste or totally empty. In order to determine the per ton costs of handling recyclable waste (payment made to the contractor), we need to calculate the total annual amount of waste collected in each container. The calculation was performed for each recyclable component separately. Equation 2 shows the calculation for 1 ton of waste recycled:

$$C_{R_i} = \frac{M_i/T_i}{\Phi_i V_i/R_i}, \qquad (2)$$

where M_i is the annual lump sum charged by a contractor for maintaining a recycling container and for handling the waste disposed into the container, T_i is the number of removals per year, V_i is the container volume, Φ_i is the waste at the time of removal as a fraction of the container's capacity and R_i is the volume-to-weight ratio

The calculation was performed for each component separately and then for the bundle, on the basis of the survey data. In order to obtain the average weighted cost of the bundle, C_R, costs were multiplied by the relative weight of each component (see Table 4).

The cost of handling recyclable waste varies from municipality to municipality. We performed a regression analysis based on our survey data, using dummy variables for region, size, and type of municipality. The regression was performed using data from those municipalities where recycling is practiced today. The coefficients of the dummy variables provide estimates for the cost adjustments required to account for the aforementioned variables. The regression results reveal an added cost for recycling in regional, small, and peripheral municipalities. These added costs can be attributed mostly to the presence of economies of scale in waste recycling (Folz 1999) as well as to the location of recycling plants (the plants have central collection points in the central region of Israel).

The C_R value displayed in Table 4 is the average cost for a large municipality located in the central region of Israel. The cost for regional, small, and peripheral municipalities is ~10–20% above the basic cost; see column 5 of Table 5 for the difference in C_R (in column 5, C_R - P_R is reported, but as P_R is the same for all types of municipalities, the differences between the different types of municipality represent the differences in the value of C_R). The values in columns 5–9 represent those values that would be obtained if the municipalities would adopt recycling.

Table 5 MSW management characteristics by type of municipality

Type of municipality	(2) No. of recyclable-waste collection rounds per week	(3) Average annual MSW (1000 tons)	(4) Average annual MSW per capita (tons)	(5) Average recycling costs, per ton of recycled waste C_R - P_R (NIS/ton)
Large	3.1	119.9	0.58	205
Medium-sized	3.3	22.1	0.55	218
Small	3.0	4.7	0.51	277
Regional	2.2	7.2	0.62	337
Total	2.9	31.8	0.56	264

Type of municipality	(6) Average landfill costs, per ton of landfilled waste (NIS/ton)	(7) Average cost savings, per ton of recycled waste, gained by reducing landfilling, C_H (NIS/ton)	(8) Average cost savings gained by recycling (% of total waste management costs)	(9) Average start-up costs, per ton of recycled waste, w_R (NIS/ton)
Large	280	430	18%	546
Medium-sized	216	295	9%	1085
Small	245	391	8%	2877
Regional	227	337	5%	1859
Total	239	360	11%	1864

Estimation of Costs Saved by Reducing Landfill Disposal

In this subsection, we calculate the costs saved by reducing the amount of waste that needs to be sent to the landfill. This parameter, C_H, is defined as total savings on landfill costs (at all segments of the waste-handling process) when the municipality decides to recycle some of its waste, per ton of (assumed) recycled waste. It is equal to the difference between total costs associated with landfill disposal when the municipality sends all of its waste to the landfill and those same costs when some of the waste (i.e., the assumed maximal attainable amount: 70% of each of type of recyclable waste) is recycled, divided by the amount of recycled waste.

The savings gained by the municipality due to recycling result from less waste being placed in general mixed-waste containers, as recyclable waste is placed in separate containers (the total costs of recycling are calculated separately and equal C_R). Therefore, the general mixed-waste containers may be emptied less frequently, thus reducing the number of workers and vehicles needed to collect the waste for landfill disposal and/or the number of collection containers (thus saving on the acquisition and maintenance of containers). In addition, the municipality sends less waste to the landfills and therefore pays less for transport and landfill (see Folz 1999 or Ackerman 1997).

A crucial point is that if the municipality takes advantage of the reduction in the volume of waste disposed into mixed-waste containers, it may save more than the relative portion of waste that is recycled (as measured by weight). This is because the municipality's costs at the collection segment of the waste-disposal process (the segment preceding the transport of waste from the transfer station to the landfill, consisting mainly of placing and maintaining waste containers, collecting the waste, and transporting it to the transfer station) are determined by volume, and the average volume-to-weight ratio of recyclable waste is twice the average volume-to-weight ratio of general waste. As mixed-waste containers are available for each building but containers for collecting recyclable waste are located only in central locations within the municipality, cost savings due to the reduced volume of mixed waste (through a reduction in the number of containers per building and/or a reduction in collection rounds) far outweigh added costs due to the increase in recycling-bound waste volume.

In order to estimate savings, we first calculated the municipality's costs of disposing all of its waste to landfill. We then estimated the reduction in waste designated to landfilling that could be achieved through recycling and calculated the cost associated with disposal of the remaining waste to landfill. For both calculations, we assumed the same level of quality and service. The difference amounts to the savings achieved by reducing total landfill disposal costs.

We constructed an optimal collection simulation, performed by computer: We inserted the specific cost parameters for each municipality, first assuming all of the waste is collected for landfill disposal and then assuming 70% of recyclable waste is sent to recycling. The difference amounts to potential cost savings. We then divided the calculated total savings by the assumed amount of recycled waste, in order to arrive at the value of C_H

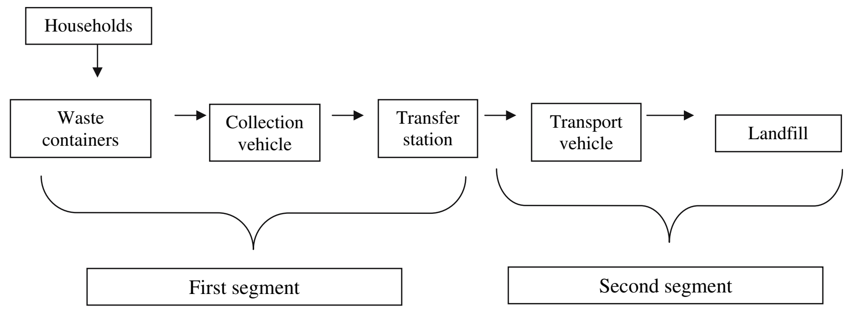

Fig. 2 The flow of waste to landfill

(measured in units of NIS per ton). In the following subsection we explain in detail the theoretical basis of our calculations.

The Costs of Landfill Waste Disposal

Figure 2 shows the flow of waste from the general mixed-waste container to its final disposal at the landfill site. As shown in Figure 2, the process of waste disposal to the landfill is comprised of two segments. The first segment (or "collection segment") includes the accumulation of waste in curbside containers, its collection via a compression truck, and its transport to the transfer station. Either municipal employees or contractors perform the work associated with this segment, with overall costs depending on the costs of purchasing and maintaining the containers, the number of containers required, and the number of vehicles and employees needed to handle the waste until it reaches the transfer station. There are also fixed operating and supervision costs.

The second segment begins at the transfer station. It includes treatment of the waste at the transfer station, transport via trucks to landfill sites, and, finally, burial at the landfills. Private companies usually operate this segment, and costs are determined by the weight of waste handled (cost per ton). A flowchart explaining the calculation of the cost, C_H, is presented in Figure 3.

The anticipated reduction in the amount of landfill-destined waste as a result of recycling is shown on the left side of the flowchart. The overall costs associated with landfill disposal are shown on the right side of the flowchart. Both sides are divided into two segments. Savings due to the anticipated reducing in landfill-destined waste are obtained by multiplying the relevant percentage reduction (measured by volume for the first segment and by weight for the second segment) by the costs associated with each segment. Cost savings per ton of waste are derived by dividing total savings by the quantity (in tons) of waste sent to recycling.

Total costs associated with disposal of waste to landfill (X + Y in Figure 3).

Equation 3 describes the calculation of the total annual cost of landfill waste disposal, for a representative municipality (the municipality index is omitted):

$$X_{(i,j,k)} = \omega + \sum \theta_i(\Psi_i + \chi_i) + \sum V_j(H_j + S_j) + \sum Z_k(L_k)$$

$$Y = q\{F + G + TP\} \tag{3}$$

the variables are defined as follows:

Components of landfill waste-disposal costs:

$X + Y$ Total costs of landfill waste disposal

q Quantity of waste in the municipality (tons)

First segment costs: X (see Figure 3)

Fixed costs

ω Cost of overhead and fixed costs to the municipality

Containers

Ψ_i Annual return on capital (by number of years, cost and interest) on each type i container

χ_i Container maintenance costs

θ_i Number of type i containers in the municipality

Collection vehicles

H_j Capital annuity (by number of years, cost and interest) on type j collection vehicles

S_j Current costs of type j collection vehicles (maintenance, fuel, and fixed costs)

V_j Number of type j collection vehicles in the municipality

Workforce

L_k Number of type k workers

Z_k Wage costs of type k workers

Second segment costs: Y (see Figure 3)

F Cost of treating a ton of waste at the transfer station

G Cost of transporting a ton of waste from the transfer station to the landfill

TP Cost of treating a ton of waste at the landfill (including burial)

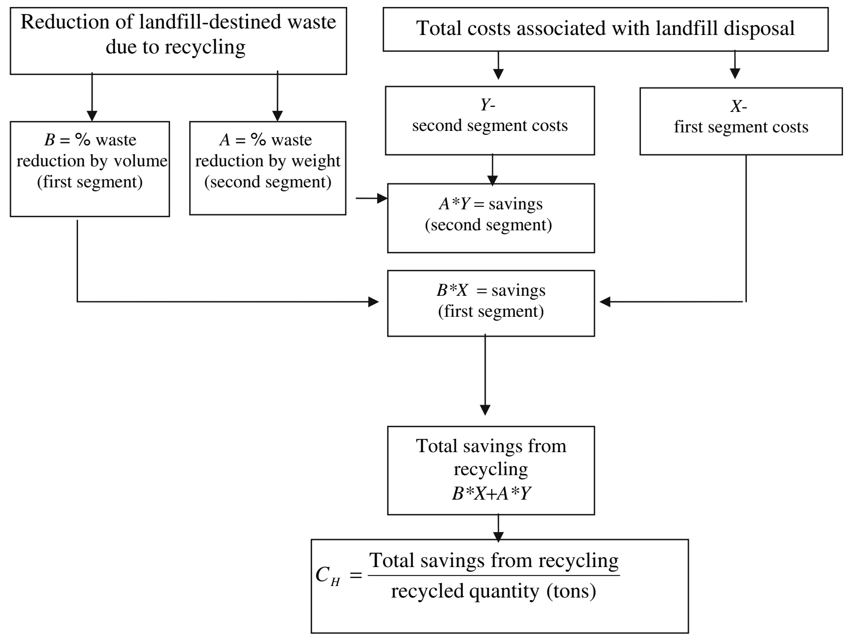

Fig. 3 Evaluation of cost savings obtained by recycling

In order to calculate savings obtained by reducing the amount of landfill-destined waste (C_H), we divided the process into the aforementioned two segments: the first segment consisting of container purchase and maintenance, collection of waste from containers, and transport of waste to the transfer station, and the second segment consisting of waste treatment at the transfer station, transport to the landfill site, and treatment and burial at the landfill site.

Savings in the second segment (transfer station to landfill site).

Operations in the second segment are carried out jointly for several municipalities. Costs are determined by waste weight: As the weight decreases so do costs, linearly. Therefore, savings equal the weight of the waste sent to recycling (by ton), multiplied by total handling and treatment costs of a ton of waste in the second segment.

Savings in the first segment (container purchase and maintenance, collection, and transport of waste to the transfer station).

This segment includes both fixed and variable costs. Fixed management and supervision costs are not expected to change due to the adoption of recycling, as it is reasonable to assume that following the introduction of recycling, the existing mechanisms will deal also with the management and supervision of the recycling program.

Variable costs are determined by the number of containers in the municipality and by the number of vehicles and workers needed to handle the waste. Both of these depend on many components, some techno-economic and others related to the type and quality of service the municipality wishes to provide its residents. The assumption is that the components related to the type and quality of service will not change with the adoption of recycling; changes will only relate to the techno-economic parameters.

The number of containers, vehicles and employees depends mainly on the volume of waste in the containers. The greater the volume, the more containers needed or, alternatively, the greater frequency of collection rounds required to empty containers (hence, an increase in the required number of vehicles and workers). Therefore, by recycling some of the waste, savings will be gained through the reduction in the number of collection rounds or in the number of containers resulting from the reduction in (unrecycled) waste volume. Column 7 of Table 5 shows the differences in C_H between the different types of municipality.

The Fixed Costs of Adoption of Recycling

In order to benefit from reduced costs due to recycling, the municipality must reorganize its operations and pay a fixed investment cost (W_R). If the municipality returns to the previous waste-management system in the future, this

Table 6 Parameters of recycling

Variable	Mean	Median	High	Low	SE
C_R	411	409	532	291	62.2
C_H	358	322	1312	40	177.7
w_R	1864	1574	5865	242	1364.5
P_R	147	147	147	147	0

investment cost will not be reimbursed; therefore, it is considered sunk. The costs associated with the adoption of recycling depend on the characteristics of the municipality. In this subsection, we present the different categories of these costs. It should be noted that not all categories are necessarily relevant to each individual municipality. Fixed investment costs (W_R) have been normalized per ton of waste recycled ($w_R = W_R/q$).

The actions necessitated by the adoption of recycling are as follows:

Administrative reorganization.
The municipality must develop plans (engineering, operational, economic, educational, and informational), issue tenders, sign contracts, manage construction, organize changes in workforce and equipment, supervise these changes, and so forth. According to the responses to our questionnaire, municipalities that adopted recycling bore a fixed investment cost of about NIS 500,000 for small municipalities and up to NIS 2 million for large municipalities.

Information.
Informational and educational activities are necessary in order to increase residents' awareness of the recycling program so as to obtain significant recycling rates. Questionnaire responses indicate that this involves investment costs ranging from NIS 1 million for a small municipality to NIS 5 million for a large municipality.

Workforce reorganization.
The adoption of recycling involves the dismissal of employees due to the reduction in the number of vehicles needed to collect waste. Dismissal involves compensation payments. According to the survey, some municipalities in Israel had to pay up to 200% severance pay. Also according to the survey, a sanitation worker is employed by a municipality for an average of 15 years. Therefore, the cost of dismissing an employee is equal to 15 monthly salaries—about NIS 150,000.

Other costs.
Other costs include modification of contracts with collection and transport contractors, the transfer station, and landfill owners. The costs depend on numerous parameters, including the date of contract renewal, the terms of the contract, and the willingness of contractors to modify contracts. According to the survey, the municipalities had to pay average compensation payments (to contractors) equal in value to 16% of yearly landfill disposal costs of the amount of waste transferred to recycling.

Profit from selling equipment and vehicles.
According to the survey, the value of old vehicle scrap is equal to about 20% of original cost, and the value of old containers is negligible.

Column 9 of Table 5 shows the estimated fixed costs borne by the different types of municipality.

Results of the Empirical Analysis

The average values of C_R, P_R, C_H, and w_R are presented in Table 6.

Necessary Condition for Adoption of Recycling

The following equation determines the feasibility of adoption of recycling (per ton of waste recycled):

$$C_R - P_R + rw_R < C_H. \qquad (4)$$

The right-hand side of Equation 4 (C_H) represents cost savings obtained by a municipality that adopts recycling through the reduction of expenditure on landfill disposal (at both segments of the waste disposal-to-landfill process). The left-hand side represents the added costs born by the municipality due to the transition from 100% landfilling to a combination of landfilling and recycling, where rw_R is the return on capital on fixed investment costs (per ton per year) associated with the adoption of recycling, C_R is the per-ton cost associated with the handling of recycling-destined waste (separation, collection, and transport to the recycling plant), and P_R is the per-ton price paid for recyclable waste at the gate of the recycling plant.

From the perspective of economic feasibility, recycling is optimal for all municipalities for which Equation 4 is satisfied. As can be seen in Table 7, the potential for recycling is very high: More than half (51%) the

Table 7 Municipalities in which recycling is efficient, by type of municipality

Type of municipality	No. of municipalities in our database	No. of municipalities in which recycling is efficient	Percentage of municipalities in which recycling is efficient
Large	16	14	87%
Medium	14	9	64%
Small	33	13	40%
Regional	16	4	25%
Total	79	40	51%

municipalities should recycle, including most of the large municipalities. As these municipalities produce a very large portion of the overall amount of recyclable waste (see Table 5, column 3)—~76%—total recycling potential is 82% of the assumed maximum attainable level of recycling. Thus, the optimal level of waste recycling in Israel (out of all MSW) is 22.7% (82% × 27.66%, excluding organic waste). This analysis does not include externality costs; incorporation of externalities strengthens our results, as will be discussed later.

Table 7 shows the economic feasibility of recycling by type of municipality. As can been seen Table 7, transition to recycling is very advantageous for larger municipalities, and much less so for regional municipalities.

The significant differences in the feasibility of recycling among large, small, and regional municipalities are due mainly to the economies of scale present in recycling. Large municipalities have lower start-up recycling costs (per ton, w_R: see column 9 of Table 5) and greater leverage when negotiating with the recycling-collection companies (see column 5 of Table 5). Thus, they can benefit from greater cost reductions (see column 8 of Table 5). In addition, population density is usually greater in the larger municipalities; therefore, a larger quantity of waste can be drawn from each recycling container, also leading to reduced costs. It should be noted that our calculations regarding the efficiency of recycling for regional municipalities incorporated the possibility of cooperation between adjacent municipalities–however, our results revealed that for most regional municipalities, such cooperation would not result in recycling becoming efficient.

Expected Price Changes of Landfilling and Recycling After Municipalities Shift to Recycling

Prices of both landfilling and recycling might be expected to change if indeed more municipalities begin to adopt recycling, thus increasing the supply of recyclable waste and decreasing the demand for landfill space. As we will now explain, however, this will most likely not be the case.

In Israel, most landfill sites operate under licenses that explicitly determine the price of landfilling. As of today, there is great demand for landfill space and landfill prices remain stable only due to the fixed prices set in these licenses. Even if all potentially recyclable waste (according to our assumption of a maximum attainable level of 70% recycling) will indeed be recycled, the reduction in waste sent to the landfill will be about 12.7% (currently, municipalities recycle about 10% of all MSW; our model shows that the optimal level of waste recycling is 22.7%, so the additional amount is about 12.7% of total MSW). This reduction will clearly not occur at once but will be spread over a number of years. The annual growth in MSW is about 3%, so the expected reduction in landfill waste over the coming years due to increased recycling will be negligible and certainly not enough to induce significant changes in landfill prices.

From this perspective, the impact on prices offered by recycling plants for recyclable waste could be expected to be significant, as the amount of recycled waste could grow by up to 120%. However, prices paid for recyclable waste are determined first and foremost by the output prices faced by recycling plants. In Israel, most of the output of recycling plants is exported (at least the marginal output surplus), and world prices would not, of course, be affected by an increase in Israeli export of recycled material. Thus, prices for recyclable waste should also not be expected to change due to increased recycling levels.

A final point regarding price changes is that according to Folz (1999), the increase in recycled waste might be expected to lower the collection costs of recycling, at least in the long run. We did not incorporate this element into our analysis (which would have strengthened our results).

Incorporating the Negative Externalities of Landfilling

For the purpose of normative analysis, we also examined the anticipated impact of a landfill tax on the potential feasibility of recycling. In 2002, the Israeli parliament passed a law imposing a landfill tax of NIS 40 per ton, representing the negative externality costs associated with

Table 8 Comparison of model results and empirical data

Type of waste	C_R - P_R (NIS/ton)	Recycling (% of total waste of each type)		Recycling municipalities (%)	
		Model	Empirical data	Model	Empirical data
Newspaper and other paper	187	63%	10%	62%	20%
PET plastic	200	64%	40%	67%	46%

Source: Ministry of Environment (2003)

landfilling. To date, however, the law has not been enforced. In this subsection, we use our data to examine the impact that the landfill tax will have on the feasibility of recycling if it will be enforced. We do this by increasing the assumed costs of landfill by NIS 40 per ton.

From our analysis, it transpires that if the negative externality costs of landfill are internalized, the feasible level of recycling in Israel will reach 90% of recycling potential (i.e., 90% of our assumed maximal attainable level of recycling of recyclable materials), compared to 82% without the landfill tax. The effect of the tax is thus quite small, and it should not be expected that the tax will induce a drastic change in recycling rates. This result indicates that government policy that applies Piguvian taxes to waste disposal will not achieve a drastic change in the municipalities' behavior.

Comparison of Model Results with Empirical Data

In order to compare the results of our analysis with actual levels of recycling, we examined actual recycling data pertaining to several waste components in Israel. Table 8 presents a comparison of the results obtained from our model and the actual levels of recycling in Israel.

The empirical data do not correspond with the results of our simulations, neither concerning the overall level of recycling nor concerning the number of municipalities that recycle. Nevertheless, the difference between the two types of waste examined is noteworthy: The discrepancy between our predictions and the empirical data regarding PET plastic is smaller than that regarding newspaper, even though the cost of recycling newspaper (NIS 187/ton) is lower than that of recycling PET plastic (NIS 200/ton).

Due to the large discrepancy between the results of our model and the empirical findings, we identified those municipalities that could potentially gain the most from recycling but that, in practice, do not recycle (or recycle only a small amount of their waste), and we interviewed representatives of their sanitation and finance departments. The objective of the inquiry was to find out why these municipalities do not engage in recycling. We conducted interviews in 42 municipalities. Before the interviews, we prepared a detailed economic analysis for each municipality, showing predicted gains from recycling for that municipality.

At the beginning of the interviews, most representatives stated that they had not performed an economic evaluation and therefore were not aware of the efficiency of recycling. In other words, they presented lack of information as the main reason for not recycling. However, when asked whether now that this information was available to them they would move toward recycling, 80% of the respondents (32 out of 40) replied negatively. Those who responded negatively offered several reasons, which can broadly be divided into two categories:

1. In order to gain from recycling, a large investment would be required to finance new equipment, dismissal of employees, changes to the existing system, acquiring information, and the like. The municipality does not have at its disposal the required resources and does not wish to clash with the relevant trade unions.
2. There is much uncertainty regarding the stability of recycling costs. Municipalities reported that they had made the necessary investments in the past and had begun recycling, but after a few years the recycling companies did not renew the contracts, causing the municipalities loss of investment, new switching costs, and damage to their image (in the eyes of the residents). In comparison, the costs of landfill are known and fixed, and municipalities can sign long-term contracts with landfill sites.

The difference between the number of municipalities that recycle plastic and the number of municipalities that recycle newspaper can be traced to this second problem. In 2003, plastic recycling plants signed long-term contracts with municipalities (for 5–10 years) and offered them a fixed price for collected plastic. As a result, many municipalities decided that plastic recycling was economically worthwhile. The paper-recycling plants, on the other hand, were willing to sign only short-term contracts (for 1 or 2 years). The municipalities were presented with stable costs and prices in plastic recycling, compared with uncertainty in newspaper recycling. Fixed prices enable the municipalities to organize accordingly and save on waste-management costs.

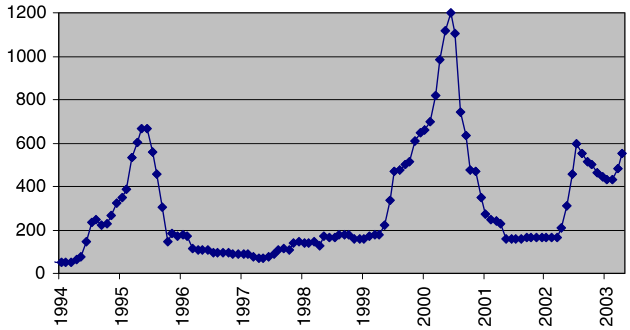

Fig. 4 Price index for recycled newspaper. Source: USA Bureau of Labor Statistics—Price Producer Index, Series Id: pcuso93#53

Uncertainty might indeed be a major factor explaining the discrepancy between the model predictions and the empirical data. This problem of uncertainty regarding prices paid for recyclable waste is a consequence of instability in the prices paid for recycled raw materials (produced from recycled waste). For example, Figure 4 shows changes in recycled newspaper price over the years.

The problem of price instability in recycling markets has been previously discussed in the literature: Eichner and Pethig (2001) argue that the instability of recycling markets may cause their dwindling and even disappearance. Ackerman (1997) claims that uncertainty in recycling markets deters municipalities from adopting recycling. Ackerman and Gallagher (2002) investigated the sharp spike in the price of waste paper in 1995, and concluded that "speculation must have played a major role in the price spike, perhaps in combination with modest effects from changes in government policy and in export demand."; the authors then discuss the implications of extreme price volatility regarding the development of an efficient recycling market, and suggest that government policy aimed at limiting such excessive volatility could be beneficial. The findings presented in this paper support their conclusion. The problem of uncertainty warrants further research.

Conclusions

In this article we presented a study conducted in Israel in the years 2000–2004. In our study, we developed an economic model of transition from 100% landfilling to a combination of landfilling and recycling, and we showed that the optimal level of recycling is much higher than usually claimed in economic literature. This result is demonstrated using an extensive empirical survey of 79 municipalities, which produce over 60% of MSW in Israel.

The economic analysis shows that if a municipality efficiently adopts recycling, it can take advantage of the anticipated reduction in the quantity of waste directed to landfills and thus reduce overall waste-management costs by an average of 11%.

The results show that for most municipalities in Israel (51% of the municipalities), it would be efficient to adopt recycling and that the optimal amount of waste recycling in Israel is 22.7% (excluding organic waste) of all MSW. The analysis reveals that recycling is very advantageous for the large municipalities (recycling is efficient for 87% of all such municipalities) and much less advantageous for the regional municipalities (recycling is efficient for only 25%). The significant differences in the feasibility of recycling among large, small, and regional municipalities is due to the presence of economies of scale in recycling. The large municipalities have lower start-up recycling costs (per ton) and greater leverage when negotiating with recycling-collection companies. Thus, they can benefit from a greater reduction of costs. Also, greater population density in large municipalities (compared to that in small and regional municipalities) also contributes to the greater economic feasibility of recycling in these municipalities, as larger quantities of waste can be drawn from each recycling container.

If we incorporate externality costs into our model, recycling potential increases to 90% of the assumed maximal attainable level (i.e., 63% of the total amount of recyclable waste). Comparison of the results obtained with and without assuming a landfill tax contradicts the widespread claim that landfill tax is necessary to make recycling economical in Israel. Our study shows that recycling is efficient even without incorporating the externality costs of landfilling and recycling. Landfill tax would indeed increase the optimal level of recycling, but not dramatically.

Actual levels of recycling do not, however, support the results of our model. The level of recycling in Israel is notably lower than our model predicts: only between 10% (for newspaper) and 40% (for PET plastic) of the total amount of waste of each type. These results imply that there are factors that hinder the transition from landfilling to recycling. Interviews with municipalities' representatives indicate several such factors. The first is lack of information: Most municipalities did not perform comprehensive economic evaluations of the alternative methods of waste management and were therefore unaware of the economic feasibility of recycling. However, a more serious problem is the combination of the large initial investment costs needed to implement recycling and uncertainty regarding the recycling market, two factors that jointly constitute a significant obstacle to the adoption of recycling. According to the literature, this problem might indeed be significant and may explain the large discrepancy between the results of our model and the actual levels of recycling.

In our interviews, representatives of the municipalities pinpointed the problem of uncertainty in recycling as constituting a major deterrent. Some of them reported that their municipalities had adopted recycling in the past but were subsequently forced to return to landfilling after only a few years, due to a steep decline in the prices paid for recyclable waste. Without a solution to the problem of uncertainty, many municipalities will refrain from making the move toward recycling, even if it is profitable.

Recommendations

Our findings suggest that the government should concentrate its efforts on the large and medium-sized municipalities, where recycling is significantly beneficial. These municipalities produce most of the waste in Israel; thus, effective government investment in this area may generate the greatest savings, as well as the greatest savings per dollar invested.

An effective government policy will have to deal with the start-up costs of recycling and with the price-uncertainty problem, and not only with lack of information on the part of the municipalities and the need to incorporate externality costs. Solving (or minimizing) the problem of uncertainty is likely to lead to a much more significant increase in recycling than standard economic instruments, such as Piguvian taxes. The government can subsidize the start-up costs of recycling and intervene to facilitate the establishment of long-term contracts between recycling plants and municipalities (e.g., by subsidizing recycling plants but conditioning the subsidy on the establishment of a long-term contract).

Unless the problem of uncertainty regarding recyclable-waste prices is dealt with, many municipalities will refrain from investing the start-up costs associated with the adoption of recycling. Without this investment, recycling is not efficient and a municipality should then avoid recycling its MSW.

Although the economic literature deals with the problem of uncertainty in recycling markets, the subject has not been modeled thoroughly and warrants further examination. This topic will be at the center of our future research.

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Appendix form for Data on Waste Treatment

1 General data

Name of municipality	Type of municipality	Contact (person completing form) + telephone for inquiries	
Population	Number of households	Number of businesses	Area of jurisdiction
Household waste (ton/yr)	Commercial-industrial waste (ton/yr)	Tree cuttings (ton/yr)	

2 Characteristics of construction in the municipality—number of residential units in each category

Ground-level	Building up to 2 stories	Building 3–4 stories	Building 5–8 stories	Building 9 and more stories

3 Collection containers

Type of container
Quantity
Purchase price
Annual maintenance costs
Average age
Times emptied per week

4 Removal vehicles (compression)

Type of vehicle
Quantity
Purchase price
Annual maintenance costs
Age of vehicle
Number of workers per vehicle

5 Labor

Type of employees	Drivers	Collection workers	Other
Number			
Total cost of monthly wages			
Number of maintenance workers			
Average Seniority			
Compensation payment upon dismissal			
Work hours per day			

6 Waste treatment sites

	Transit station	Landfill	Dry landfill	Other
Name/location of site				
Distance from municipality				
Treatment cost (NIS/ton)				

7 Cost of waste treatment (household waste only)—Removal by municipality

Maintenance of disposal container (NIS/year)	Collection and transport to transfer station (NIS/year)	Treatment at transfer station (NIS/year)	Transport to landfill site (NIS/year)	Landfill costs (NIS/year)

8 Cost of waste treatment (household waste only) – Removal by contractor

Actions included in payment to contractor	Maintenance of disposal containers (yes/no)	Collection and transport to transfer station (yes/no)	Treatment at transfer station (yes/no)	Transport to landfill site (yes/no)	Landfill costs (yes/no)
Payment to contractor (NIS/year)					
No. of years until end of contract (first option)					
Type of payment (by ton, inclusive, by number of collections)					
Cost of changing the contract due to transition to recycling					

Instructions for completing the form

1. In section 2: note the number of housing units in each category. The total should equal the number of households in the municipality.
2. In sections 4, 5, 6: note the cost actually paid, that is, the total costs including VAT (if paid).
3. In section 5: try to list the cost components to the extent possible (as noted on the form). When it is not possible to break down a given cost component, note what it includes.
4. In sections 5, 6: If the removal is done both by the municipality and by a contractor, where appropriate note which areas are under the responsibility of the municipality and which are under the responsibility of the contractor (included in the price the contractor charges).

Municipalities That Switched from landfilling to Recycling

9 Cost and quantity of recycling—current

	White paper	Newsprint	Cardboard	Glass	PET	Other plastic
No. of collection containers						
Volume of containers						
Lifespan of containers						
Percentage of utilization when removed						
Monthly cost of removal						
Distance from recycling plant						
Payment received for 1 ton at gate of recycling plant						
Quantity of monthly waste for recycling (tons)						

10. Other Current Costs/Savings

10a Reduction in number of removal vehicles (compression)

Type of vehicle
Quantity reduced
Sale price obtained
Annual maintenance cost
Age of vehicle
Number of workers/vehicle

10b Dismissal of employees (due to reduction in general waste)

Type of employees	Drivers	Collection workers	Other
Number dismissed			
Average cost of monthly wages			
Average time on the job			
Average compensation payment upon dismissal			

10c Reduction in number of collection containers

Type of collection containers
Number reduced
Average sale price obtained
Average annual maintenance costs
Average age

10d. One-time costs of transition to recycling

1. Cost of information campaign – budget allocation for transition to recycling, including type of actions and budget.
2. Organization costs—one-time cost of organizing.

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