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Air Pollutant Emission Standards and Guidelines for Municipal Waste Combustors: Economic Analysis of Materials Separation Requirement (Program Approach)

NSPS

CONTENTS

1. SUMMARY

Costs were estimated for a subset of 171 municipal waste combustors (MWC's) (out of a total population of 280 planned and existing MWC's) that were assumed to incur incremental costs as a result of the federal regulations. The excluded MWC's were either located in states with existing recycling programs and goals or were below a predetermined size cutoff. The costs were computed using various assumptions about avoided disposal costs and scrap revenues. The final costs for the rule ranged from $58 million per year to a savings of $345 million per year.

The separation costs estimates were dominated by collection and processing costs for recyclables, although administrative costs were included in the totals. The cost savings resulted principally from a combination of scrap revenues, avoided landfilling costs, and avoided trash collection costs. The modeling scenarios were designed to show variations in the avoided cost of trash collection and disposal as well as scrap revenues. Scrap revenues did not vary dramatically, given the model assumptions; the difference between the two scrap scenarios was about $43 million per year. The disposal/collection assumptions did make a substantial difference, however. The alternative assumptions accounted for a $182 million difference in avoided disposal costs for existing MWC's and a $177 million difference in avoided trash collection costs.

Costs per ton of waste combusted (after the rule is in place) ranged from $2 per ton to a savings of $12 per ton. The cost per ton of waste diverted ranged from $5 per ton diverted to a savings of $29 per ton diverted.

2. APPROACH

2.1 MUNICIPAL WASTE COMBUSTOR DATA

The population of municipal waste combustors (MWC's) was divided into two groups for this analysis: existing MWC's and planned MWC's. The database included 213 existing MWC's (units in service or that will be in service sometime in 1991). These 213 units were located by city and state. Similar information was developed for planned MWC's, but the designs, locations, and capacities of these units were less certain. The planned units were matched to model plant characteristics and then scaled up to a total of 67 units of varying technologies and throughput.

Overall, the data included 280 MWC's with a municipal waste throughput (capacity times utilization factor) of 53.4 million tons per year.

2.1.1 Expanded Service Areas for Existing MWC's

Since MWC's may have financial or energy output obligations that assume a certain throughput, it is important for them to maintain the pre-recycling level of operation. One way to maintain throughput is to expand the area served by the combustor; if more homes send waste to the unit, a specified fraction can be removed for recycling and the combustor would still be able to maintain its operating level.* As explained below, the waste diversion analysis concluded that in order to meet the 25 percent source separation target, 28.6 percent of the waste generated must be diverted.** Given a 28.6 percent diversion, 71.4 percent of the waste collected will still be burned. For a 100-ton-per-day (TPD) unit then, 100 = 0.714 * Q where Q is the necessary size of the new, expanded service area. If the new service

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*This assumption ignores any change in the heat content of each ton of waste after recyclables have been removed.

**The discrepancy results from the regulation's limit on the amount of yard waste that can count toward the 25 percent goal. As proposed, yard waste could account for no more than 10 percent of the credit; since assumptions concerning municipal waste composition yield a larger share of yard waste, the additional material is still diverted, it simply does not contribute to the 25 percent target.

area grows to collect 140 TPD, then 40 tons (28.6 percent) can be diverted and 100 tons will still be burned.

In general, the service areas of existing MWC's must increase by 40 percent. Thus, the original throughput of the 280 MWC's was increased from 53.4 million tons per year to 67.7 million tons per year, with the increase only affecting the 213 existing MWC's.

2.1.2 MWC's That Will Not Incur Incremental Costs from the Federal Requirement

Municipal waste combustors in several states would be forced to implement substantially similar programs because of state laws; the federal requirement would impose no incremental costs on MWC's in those states. Nine states (plus the District of Columbia) would qualify on these grounds. Each of these 10 jurisdictions have laws requiring at least a 25 percent recycling rate by 1995. States with lower targets or with similar targets after 1995 were not exempted. This assumption dramatically affected the population of MWC's analyzed in this study. The 10 jurisdictions contained 88 MWC's, or 31 percent of the 280 original units. Most of the 88 were existing units (66) and the remaining 22 were planned.

Second, MWC's with capacities of less than 40 TPD were excluded from compliance with the requirement. This assumption was made in anticipation of a similar exemption of the final rule. The assumption excluded an additional 21 existing MWC's from the economic impact analysis. Overall, the analysis focused on 171 MWC's that would incur incremental costs from the source-separation requirement. These 171 MWC's collected just over 40 million tons of MSW per year.

2.1.3 Components of the Wastestream

The composition of MSW collected was a critical factor in this analysis. The waste composition determined how much diversion was possible given varying styles of recycling programs; revenues from the sale of collected materials also depended on the material types. Many communities and even some states have conducted waste composition studies that sample incoming loads at landfills and then separate, weigh, and possibly measure the volume of various waste components. In the research supporting this analysis and in support of EPA's 1990 Waste Characterization study (the Franklin data)[1], many sampling studies were compiled describing the composition of the wastestream.[2] Waste composition data were not available for the MWC's in the database nor are site-specific studies available for a significant share of the MWC's.

Because of the detail in the composition data in the Franklin study and because of the complexity involved in modeling site-specific waste profiles, Franklin's 1988[1] waste composition data was applied to the MWC's to estimate site-specific quantities of various components of municipal solid waste (MSW). While waste composition can vary substantially based on the mix of industrial, commercial, and residential generators, climate, socioeconomic status, education, etc., reliable sources of regional waste composition estimates are not available that would be appropriate as the basis for extrapolation to particular regions of the country.

Franklin[1] estimated the composition of three different categories of MSW: MSW generated, materials recovered from the wastestream, and materials discarded (the residual of generation minus recovery). Table 2-1 summarizes the national estimates of several recoverable components of MSW, along with the estimates for total tons discarded nationally.

Yard waste accounts for a significant share of the recoverable materials (47 percent of the 65.7 million tons that is potentially recoverable) and 20 percent of total discards. Paper and paperboard products included are newsprint and corrugated and account for about 33 percent of the recoverable materials identified. The remaining materials are glass, metal cans, and selected plastic bottles.

Two important assumptions underlie use of these data. First, these national averages were applied to individual MWC service areas to compute MWC-specific estimates of the quantity of yard waste, glass containers, etc. collected in each wasteshed. Second, only certain recoverable materials were the focus for this analysis; the selection was based on judgment that these materials would likely be part of a comprehensive recycling program designed to achieve fairly high rates of diversion (e.g., 25 percent), considering their prevalence in MSW, the existence of scrap markets, and precedent for collection of the materials in existing programs. This is not to say that other materials might not be part of recycling programs or that every one of these commodities would be; instead, a representative mix of materials was selected and it was assumed that recycling programs would collect these materials. Assumptions about how the materials are collected are described

TABLE 2-1. SUMMARY OF RECOVERABLE MATERIALS MODELED IN THE MWC ANALYSIS

Waste component	Percentage of MSW disposed (%)	Quantity disposed Nationally in 1988 (million tons)
Yard waste	19.7	30.7
Corrugated boxes	8.1	12.6
Container glass	6.3	9.9
Old newsprint	5.7	8.9
Steel cans	1.5	2.2
Aluminum cans	0.4	0.7
PET soft drink bottles	0.2	0.3
HDPE milk bottles	0.2	0.4
Subtotal	42.1	65.7
Other products/wastes	57.9	90.3
Totals	100	156

Sources: Franklin Associates, Ltd.[1]

later in this chapter under the descriptions of the individual recycling programs modeled.

2.1.4 Diversion Rates

Several factors determine how much of the material disposed could actually be collected and recycled. First, materials that are contaminated may not be recyclable; water-soaked newsprint or corrugated cardboard, for example, may be worthless because of contamination. Similarly, combinations of recyclable and nonrecyclable materials may prevent recycling. Whether because of contamination or inconvenience, however, only a fraction of the quantity of these materials will be available for recovery.

A second factor to consider is the willingness of residents to participate in recycling programs. Even if a high percentage of newspaper generated is easily separated and recycled, only those households that participate in the recycling program will contribute to the diversion of material from the MWC.

A final consideration is the waste and contaminants that are mixed in with the collected materials and are ultimately discarded. Labels, closures, moisture and dirt may all be mixed with recyclables and will eventually find their way into a landfill or MWC, so this is a third adjustment necessary to calculate the net quantity of waste diverted from the MWC.

2.1.5 Research

Assumptions regarding recoverable fractions and participation rates are summarized in Table 2-2. A number of sources on potential recovery rates of various materials were reviewed and used to derive two separate estimates of recoverable percentages (to take account of contamination, losses, inconvenience) and participation rates (which vary by the type of recycling program and extent of participant motivation). Most sources report effectiveness of recycling programs in terms of total diversion; these two components were separated in order to allow modeling different participation rates inherent in different styles of collection programs (e.g., curbside versus drop-off programs). These are uncertain estimates and will vary dramatically based on the characteristics of individual communities. Nevertheless, it is important to adjust total discards of the materials to reflect realistic expectations of actual materials recovery.

As shown in the Table 2-2, recoverable fractions range from 60 to 90 percent. Net diversion rates (the product of recoverable fractions and

TABLE 2-2. SUMMARY OF MATERIAL RECOVERY ESTIMATES

Waste component	Percentage of MSW disposed (%)	Percentage recoverable[a] (%)	Net diversions given 80 percent participation (%)
Yard waste	19.7	90[b]	72
Corrugated boxes	8.1	75[c]	60
Container glass	6.3	87[d]	70
Old newsprint	5.7	87[e]	70
Steel cans	1.5	60[f]	48
Aluminum cans	0.4	90[g]	72
PET soft drink bottles	0.2	75[h]	60
HDPE milk bottles	0.2	60[i]	48
Totals	42.1		

[a]Fraction of materials recoverable from household waste stream correcting for losses, contamination, inconvenience, etc. Several of these estimates were derived by dividing estimates of net diversion by the participation rate.

[b]NRDC estimate from testimony before the EPA Materials Separation Workshop, February 15, 1990, p. 9.

[c]May be high for households, but consistent with commercial corrugated recycling rates.

[d]Considers NRDC's 65 percent net diversion rate and higher rates achieved in other types of programs (e.g., deposit laws).

[e]Slightly above the 65 percent net diversion rate cited as a target by NRDC and as a projection by Andover International Associates, Resource Recycling, April 1990, pp. 70+.

[f]Given an 80 percent participation rate, the net diversion would represent about a 50 percent increase above current recycling (just over 30 percent for steel beverage cans).

[g]Assumes virtually all cans are recoverable. Diversion rate of 72 percent is well below that of some deposit states.

[h]Based on a net diversion rate of over 50 percent which as been achieved in deposit programs.

[i]Very limited experience with recovery of these containers.

participation rates) range from 48 percent for milk bottles (for which there is little precedent for recycling thus far) up to 72 percent for yard waste and aluminum cans.

The notes to the table explain the assumptions and sources behind the recoverable fractions. In some cases, estimates were obtained from secondary sources, but in other cases estimates were based on judgment or derived from a source that cited the overall diversion rate. Given a 70 percent net diversion rate and an 80 percent participation rate, for example, the recoverable fraction must be 0.87, or 87 percent.

An 80 percent participation rate was selected as applicable to recycling programs that provide curbside pickup of materials.* According to the sources reviewed (further discussion of the recycling programs that were modeled appears later is this chapter), participation rates for curbside programs ranged from 3 to 98 percent. In the data reviewed, 49 programs reported participation rates and 14 of them cited rates of greater than 80 percent, so this participation rate is viewed as an optimistic, but realistic, estimate.

The effect of these recoverable and participation rates is to decrease the total quantity of waste that is diverted from MWC's as a result of recycling. Table 2-3 integrates the information on waste components with the net diversion rates to compute the share of MSW diverted from MWC's. Given implementation of a recycling program that covered all of these materials, an 80 percent participation rate would divert nearly 29 percent of the MSW disposed. The "extra" diversion above the 25 percent target is discussed next.

2.1.6 Adjustment to the Diversion Rates

Two adjustments were made to the diversion rates: the first incorporated the 10 percent cap on credit for yard waste recycling and the second accounted for contaminants collected with recyclables that are ultimately discarded rather than recycled.

The regulation stipulates that regardless of how much yard waste is collected, it can only contribute 10 percentage points of the 25 percent

*Given the high separation target, curbside collection is the most likely to provide the high participation rates necessary to meet the target. Drop-off or buy-back centers may be sufficient in some settings or for some materials, but participation tends to be much lower.

TABLE 2-3. SUMMARY OF DIVERSION ESTIMATES FOR MWC's

Waste component	Percentage of MSW disposed (%)	Percentage of MSW Diverted by Recycling: Total diversion (%)	Percentage of MSW Diverted by Recycling: With 10 percent cap on yard waste (%)
Yard waste	19.7	14	10
Corrugated boxes	8.1	5	5
Container glass	6.3	4	4
Old newsprint	5.7	4	4
Steel cans	1.5	0.7	0.7
Aluminum cans	0.4	0.3	0.3
PET soft drink bottles	0.2	0.1	0.1
HDPE milk bottles	0.2	0.1	0.1
Totals	42.1	29	25

Notes:

Percentage diverted is based on net diversion rates shown in Table 2-2.

Totals may not add because of rounding.

target: other materials must make up the remaining 15 points. Calculations of diversion rates and participation demonstrate that over 14 percent of the wastestream could be diverted from yard waste recycling, so the actual share diverted will exceed 25 percent. Table 2-3 also summarizes the percentage of MSW diverted once the cap on yard waste is included. The analysis assumes that the additional material would still be collected and the appropriate costs and offsets, such as avoided disposal costs, would still accrue to the community.

The second adjustment made was for contamination of recyclables. Moisture, dirt, labels, or other nonrecyclable materials often are included with recyclables. Data from 72 operating and planned material recovery facilities (MRF's) that handle a mix of recyclables indicate that the average waste factor is 9.7 percent.[3]

The adjustment did not affect the recycling target since all the material collected in the recycling program was originally separated and would count toward the 25 percent goal. In computing the tonnage that would avoid trash collection and disposal costs, the quantity of material collected was reduced by 9.7 percent. A similar adjustment was made before computing scrap revenues.

To summarize the adjustments to waste quantity recycled, the total quantity of recyclable materials currently sent to MWC's was first estimated. Adjustment factors were applied to these estimates to reflect the ease of recovery (the recoverable fraction). Then participation rates were used to further adjust the quantity of material collected. The final estimate of waste diverted from landfills is adjusted by a waste factor that equals approximately 10 percent of the weight of material collected. Recycling programs are designed to collect the total quantity of recyclables taking into account the recoverable fraction and participation rates. Avoided disposal costs are computed based on the tonnage ultimately diverted from MWC's, which includes the waste factor.

2.1.7 Recycling Programs and Costs

The model developed provided several alternative recycling program options. The options included in the MWC analysis were:

- Curbside collection programs for all the modeled materials except yard waste;

- The MRF's that may be combined with a curbside program to provide for separation and processing of collected materials; and
- Compost programs for yard waste that include curbside collection and centralized processing of the material.

Various combinations of these three programs were also modeled. Given the assumed participation rates associated with each and the mandatory 25 percent recycling target, only two program scenarios could achieve the desired diversion rate: compost plus curbside collection, and compost plus curbside collection and an MRF. Either option would meet the 25 percent target, even taking into account the 10 percent cap on yard waste credit.

Unit cost data were compiled from secondary sources for curbside, MRF's, and compositing programs. All costs in the model were based on reported data from existing programs and were expressed in annualized costs per ton of recyclables collected assuming 260 operating days per year. The costs reflect annual operating costs and amortized capital costs assuming a three percent real discount rate.* Where the reported capital expenses were listed as depreciation charges, the depreciation charges were used for the annual capital costs. Finally, all costs were scaled to 1989 dollars.

2.1.8 Methodology for Estimating Recycling Program Costs

Cost estimates for each type of program were derived from statistical analyses of empirical data from existing programs. Since recycling programs can vary tremendously, the relationship between cost and several cost determinants for each type of program were analyzed. The factors analyzed were the size, design, level of technology, and collection method of the recycling program. For example, the cost of a curbside collection program would depend on size in terms of the quantity of material handled and the number of households served. Also, program design considerations such as the materials collected, pick-up frequency, and the degree of household separation (commingled or separated) affect cost. Beyond this, factors that contribute to the effectiveness of a program, such as whether participation is voluntary or mandatory, must also be considered.

After some preliminary analysis, the primary recycling program cost determinant was found to be the program size in tons of materials handled.

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*The amortization period was 20 years for buildings and 7 years for most other costs (e.g., trucks and storage bins).

While other factors may also be significant, the data were insufficient to allow estimation of their effect on costs with any degree of confidence. Therefore, the relationship between the program size and cost was analyzed for all the program types. From these relationships, cost functions were determined relating the program's cost to its size in tons per day.

To define each program's cost function, regression analysis was used to test the ability of waste throughput to predict recycling program costs. Each program was tested with two functional forms: a linear relationship, and a linear relationship in logarithmic form. The better of the two cost predictors was used in the model, and if neither was a good predictor of cost, the cost was set to the sample average in dollars per ton.

2.1.7 Curbside Collection

Curbside collection programs involve collection of recyclables at the point of generation. Households typically place materials in bins or bags at the curb on specific recycling days or on trash days. The materials collected in the curbside programs were assumed to be container glass, newsprint, aluminum and steel cans, certain PET and HDPE bottles, and corrugated cardboard (see earlier section in Chapter 2 for a description of the recyclables assumptions). The hauler was assumed to collect the material and transport it to a central facility where the materials are unloaded. Materials may be sold as they are collected, or they may be processed at an MRF.

Cost data were compiled for curbside programs from secondary sources ranging from trade journal articles to municipal reports on curbside collection. Although there are more than 1,500 curbside programs in operation across the United States,[4] reliable data on their costs are scarce. Of the 60 curbside programs initially evaluated, the cost data necessary to calculate a total cost per ton were only found for 31 programs. The final database included programs serving populations ranging from 1,186 to 500,000 people.

The cost of curbside collection programs is positively related to the tons of material collected. Increasing the quantity of recyclables collected results in a larger program with higher capital costs, as well as higher operating costs due to the increased labor needed for collection, processing, and administration. Curbside programs do demonstrate economies of scale, however. Although the total program costs increase with throughput, the cost per ton declines because capital and labor can be used more efficiently in the larger programs.

The regression analysis resulted in a curbside collection cost function of:

$$Y = 132.6 * Q^{-0.235}$$

where Y represents the annualized cost per ton and Q represents the quantity of recyclables collected in TPD. Program sizes in the database range from 0.26 to 22.6 TPD, yielding a program costs per ton range of $218 to $64. For larger programs (greater than 22.6 TPD), costs were assumed to remain flat at $64 per ton because data were inadequate to justify an assumption that economies of scale would continue to decrease the cost per ton.

2.1.8 Material Recovery Facilities (MRF's)

In this analysis, MRF's were used to provide a centralized point for processing recyclables collected in a curbside program. The MRF's separate and prepare materials for marketing to end users such as paper mills or glass plants. Their primary function is to improve the marketability of collected materials (by cleaning, separating, baling, etc.) and therefore command higher prices for the recyclables.

Cost data were compiled from a MRF database that reported considerable information on operating characteristics as well.[5] The database included entries for 40 existing MRF's and 64 planned MRF's. However, complete data on capital and operating costs were available for only 51 of those facilities. If available, tipping fees (the price charged to process recyclables) were used as the indicators of MRF costs. If tipping fees were not reported, cost estimates were based on reported capital and operating costs. The final database included 51 programs ranging in size from 2 to 385 TPD.

A statistical analysis revealed that for MRF's, size was a poor predictor of cost. Since no reliable function relating size and cost could be derived, the MRF cost was set to the sample average in dollars per ton. The observed costs per ton ranged from $1.56 to $71.46 per ton, with an average cost of $21.79 per ton. Therefore, the estimate of MRF cost was set at a flat rate of $21.79 per ton.

2.1.9 Centralized Composting

It was assumed that yard waste was collected at the curb and processed in centralized composting facilities. Composting programs vary in the types of yard waste collected and the level of technology employed. Higher technology approaches use machines to turn and aerate the compost, whereas the lower technology approaches involve no machinery. Although both approaches produce the same result, the lower technology approach requires more land and time to yield the same quantity of compost.

Cost data were compiled from secondary sources, including EPA studies, municipal studies, and trade journals. Although more than 600 centralized composting programs operate in the United States,[4] reliable data were available for just 50 programs. Of these 50 programs, complete cost data were available for only 10 programs.

The cost of composting programs is positively related to the quantity of yard waste collected. Similar to curbside collection of recyclables, increasing the quantity collected results in both higher capital and operating costs. However, composting programs also demonstrate economies of scale, causing the cost per ton to decline with increasing quantity collected.

Regression analysis resulted in a centralized composting program cost function of:

$$Y = 60.30 - (1.66 * Q)$$

where Y represents the annualized cost per ton and Q represents the quantity of yard waste collected in TPD. Program sizes in the database ranged from 0.45 to 25 TPD, yielding a program costs per ton range of $60 to $19. For larger programs (greater than 25 TPD), it was assumed that costs would remain flat at $19 per ton.

2.1.10 Selection of Program Alternatives

The assignment of MWC's to each type of program was determined by the net cost of the various program options (i.e., program costs net of scrap and disposal offsets as appropriate). The model's objectives was to achieve the 25 percent target in the least expensive way. MWC's were assigned to either compost plus curbside or compost plus curbside plus MRF, whichever was cheaper. The MRF may have been a good investment if scrap prices were relatively strong in the region and further processing of the scrap would increase revenues enough to cover the capital and operating costs of the MRF. The modeling is discussed in more detail later in the chapter.

2.1.11 Limitations

Although there are a large number of recycling programs in the United States, reliable and complete cost data are available for only a small number of programs. In addition to the small number of programs for which reliable data are available, it is uncertain how representative the database sample is of the total population. Both of these factors contribute to the uncertainty of the cost function estimates. These and other limitations are discussed in more detail in Chapter 4.

2.1.12 Other Costs

The model also included costs for two other activities resulting from the regulation: measuring compliance with the 25 percent target, and administering the program. These costs were imposed uniformly on MWC's based on several simplifying assumptions.

Measurement costs were computed by assuming that all MWC's would install electronic scales to weigh incoming loads. The MWC would keep records of past and current acceptance rates to document changes in the unit's throughput and records of materials collected to show that the diversion rate was being achieved. Costs were included only for the purchase, maintenance, and operation of the scale; no recordkeeping costs were added. Annualized costs were set at $3,800 per year assuming a 3 percent discount rate.[6]

Administrative costs were based on an annual cost assumption of $35,000 per 25,000 population in the service area.* Waste throughput was converted to population using a generation rate of 0.68 tons per person per year.

2.1.13 Avoided Costs

Establishment of a source separation and recycling program would provide savings to the community in three different areas:

- Avoided landfilling costs for waste shifted from land disposal to existing MWC's, assuming that existing MWC's would seek to maintain the current MWC throughput by expanding the area from which waste was collected. Communities would save the cost of landfilling waste that was shifted to the MWC.

*Costs were based on site visits conducted in New Jersey.

- Savings resulting from "downsizing" planned MWC's. Because over 28 percent of the planned MWC throughput would be diverted through recycling, the planned MWC's could be redesigned smaller than originally intended, saving on construction and operation costs.

- Savings on trash collection at all MWC's. The waste diverted from the combustor by the recycling program would not be collected as regular trash, thus saving on collection costs.

2.1.14 Landfill Savings at Existing MWC's

The most important assumption involved in computing this savings was the modeling assumption that existing MWC's would expand their service areas to collect more waste than they do already. All of the "new" waste brought into the service area was assumed to be drawn from nearby landfills, so the avoided cost should be appropriate to those neighboring landfills.

Estimates of the full cost of disposal developed by the Office of Solid Waste (OSW) in support of the Regulatory Impact Analysis for revised criteria for municipal solid waste landfills were used to estimate the avoided landfilling costs.[7] The cost estimates included both the current or baseline cost of disposal plus incremental costs attributable to the revised criteria. The costs were specified for seven different size categories of landfills and for five alternative design scenarios that address the range of designs likely to be required after the regulations are effective. Weighted average costs were computed based on the predicted incidence of each landfill design.

Averaging costs across size categories, however, was deemed unreliable because of the broad range in costs across sizes (i.e., the substantial economies of scale in landfill costs). Disposal costs per ton varied by as much as a factor of 10 between the largest landfill size category and the smallest. For this analysis, therefore, disposal cost savings were estimated under two different scenarios, each using a different aggregation of these costs across sizes.

A landfill-by-landfill average of costs resulted in a disposal cost estimate of $62.60 per ton. If a tonnage-weighted average was used (each ton of waste disposed counts equally instead of each landfill unit), the disposal cost estimate was $20.24.[8] The landfill-based average is simply too high, given the huge fraction of waste disposed in the largest landfills. In addition, MWC's are likely to be located in high population, high density areas where larger landfills are more typical.

To define a range of disposal cost savings for this analysis, the average of these two estimates ($41.42 per ton) was used as an upper bound and the tonnage-weighted estimate of $20.24 per ton was used for the lower bound. The costs were computed as the savings per ton of waste diverted from the landfills. The total tons diverted equalled only those recyclables that were collected and sold; the fraction of the recyclables that were not marketable (the contaminants) were eventually returned for disposal, so no savings was credited.

These estimates assumed that the full cost of disposal was "avoidable," that is, removing a ton of waste from a landfill would save the full cost per ton of disposal in that landfill. In fact, only a portion of the cost may be avoidable. Nevertheless, this range was used to bound the disposal cost savings for this analysis. The results were quite sensitive to these assumptions, as shown in Chapter 3.

2.1.15 "Downsizing" Savings at Planned MWC's

MWC's that are still in the planning stage could accommodate the projected decrease in throughput most efficiently by simply reducing the scale of the project. For this analysis, this approach was assumed to be adopted by all planned MWC's. The savings were estimated by estimating the total annualized cost of constructing and operating planned MWC's, given compliance with the air emission requirements, and then computing the savings in these costs if waste flows were reduced.

The savings was computed in terms of tons of waste diverted from the planned MWC's and was set at $37.59 per ton. As with the avoided landfilling costs, the unit savings was multiplied by the actual tons of recyclables diverted and sold. Contaminants in the recyclable mix did not produce savings.

2.1.16 Trash Collection Savings at all MWC's

Any material collected and sold under a recycling program would no longer be collected by a trash hauler, so savings were computed for each ton diverted and sold, whether the waste was destined for an existing MWC or a planned unit.

The estimated savings per ton was computed in two stages. The first was to identify the current cost of trash collection and the second was to compute the portion of those costs that could be avoided if waste volume declined. The current cost of trash collection was computed from empirical data of collection costs from a national survey.[9] The survey was not an exhaustive one, as costs were extracted for collection services for only 63 communities across the country serving populations ranging from 2,000 to nearly 1 million. A significant relationship between community size and cost was not apparent, so an average was calculated for the 63 communities of $45.30 per ton (in 1989 dollars). The actual data ranged between costs of $11.80 per ton and $83.60 per ton.

In this analysis, it was assumed that only a fraction of the trash collection cost was avoidable. Since many aspects of the collection program would remain unchanged (e.g., the routes still must service the same area and the same stops), only certain elements of the program's cost could be saved by reducing the average amount of waste collected per stop. Only a limited amount of data were available describing collection costs and none of the sources explicitly dealt with savings from reduced waste flows.

In the absence of independent data on avoided trash collection costs, the avoidable percentage of trash collection cost was linked to the avoidable percentage of disposal costs. Two different percentage factors were used to adjust costs. In the short run, it was assumed that only variable costs could be avoided; across the landfill sizes analyzed, the avoided cost percentage was 24 percent or $10.87 per ton when applied to the trash collection cost. Over the long term, savings would be possible on capital equipment as well; given the cost functions for landfills and a 25 percent waste diversion, the avoided cost percentage was 59 percent or $26.73 per ton when applied to trash collection costs. As with the avoided disposal and downsizing savings, the savings per ton were applied only to recyclables that were collected and sold. Using these landfill-based percentages for computing avoided trash collection cost introduced uncertainty in the estimates, since the approach implies that the cost structure for collection and disposal are similar.

2.2 SCRAP REVENUE

The model also included scrap revenue for most of the materials collected by the recycling programs. Scrap prices for various commodities were taken from region-specific price summaries reported regularly in Recycling Times. The only exception was for yard waste/compost, which was assigned no market value. Price data were compiled for the first 7 months of 1990 only.

These scrap prices cover seven regions of the country and represent quotations provided by various purchasers of scrap materials during the given period (i.e., prices they paid). The sampling is not random and no statistical conclusions can be reliably drawn from the data, but they do provide indications of regional price levels and trends over time. If a range of prices was quoted for a given region, the newspaper reports the highest and lowest quotes they receive. In addition, data on scrap prices across the country are not readily available, so this provided a quick and inexpensive source of the price information.

2.2.1 Modeling Approach

Scrap prices for each material were computed for two different markets. The first market was prices paid by "processors," defined by Recycling Times as scrap dealers, brokers, scrap yards, and municipal centers. The second set of prices was for "end users/mills," which are mills, foundries, factories, or other plants where the material is actually reused. This material was assumed ready to enter the plant for recycling as opposed to the material sold to processors, which is likely to undergo further processing and consolidation before it is shipped to an end user.

In the analysis of recycling progress, these two markets were used as proxies to indicate the differences in potential revenue to programs that sell materials to intermediaries for further processing and those that process the material themselves and sell to end users. In the model, communities choosing the curbside recycling option sell to intermediaries and earn the processor prices, while communities with curbside plus a MRF earn the end-user prices.

In addition to the different markets, scrap revenues were computed for seven materials based on two different scrap price scenarios. A "current" scrap price scenario was derived from the average scrap prices offered for each material and for each of the seven regions. This scenario averaged the prices paid over the first 7 months of 1990; if prices were reported over a range, the midpoint of the range was used in the average.

Because of concerns with increased supply driving down prices, a lower scrap price scenario was developed. Under this scenario the lower end of price ranges reported in January through July 1990 was averaged. Clearly, prices could well fall below this range, but without additional research into the price response of the various scrap markets to increasing supply, it was not possible to estimate a lower bound. In addition, exogenous factors such as energy prices and prices of substitute materials (e.g., virgin material inputs) could dramatically affect scrap prices, making projections extremely uncertain.

2.2.2 Price Data

Table 2-4 summarizes the scrap price data used in the analysis. Regional price differences are apparent for every material; for corrugated and newsprint, prices are negative in the Northeast and Mid-Atlantic at least in some market scenarios. Revenues per ton are the highest, by far, for aluminum and even through aluminum only accounts for a small share of municipal waste disposed, aluminum revenue is still the largest single contributor to total revenue. Again, these prices represent relative price levels between materials and regions. Many other factors affect the prices actually paid and the trend in prices in the future. As a result, the scrap price estimates should be evaluated cautiously.

2.3 MODEL STRUCTURE

To conclude this chapter, the integration of each of the components of the analysis described above is summarized. Most of the components of the modeling simply contribute additional data to the database. The raw data included only MWC location and size. From this point:

- Waste quantities were adjusted to reflect larger service areas for existing MWC's;
- The quantity of each recyclable material generated within each MWC's service area was computed based on the Franklin data[1] on waste composition;
- The potentially recoverable quantity and the actual quantity diverted for each recyclable material in each MWC service area was computed using the potentially recoverable fractions and participation rates, respectively;
- Scrap values for each recyclable material (given current and lower scenarios and prices paid by both processors and end users) were added. Prices were matched to individual MWC's based on the state in which they were located; and

TABLE 2-4. SUMMARY OF SCRAP PRICES USED IN THE MWC ANALYSIS
(dollars per ton)

Current Scrap Price Scenario

Region	Old Newsprint Processor ($)	Old Newsprint End-User ($)	Corrugated Processor ($)	Corrugated End-User ($)	Glass Containers Processor ($)	Glass Containers End-User ($)	Steel Cans Processor ($)	Steel Cans End-User ($)	Aluminum Cans Processor ($)	Aluminum Cans End-User ($)	PET Processor ($)	PET End-User ($)	HDPE Processor ($)	HDPE End-User ($)
South	8	16	15	38	26	61	58	58	733	911	136	136	97	97
South-Central	7	18	21	41	9	60	67	67	753	939	100	100	86	86
West	9	32	27	60	53	64	56	56	832	1,255	121	121	60	60
Northeast	-10	18	3	27	25	33	58	58	641	1,011	156	156	92	92
East-Central	7	14	16	29	28	54	61	61	732	989	156	156	100	100
West-Central	8	21	16	28	27	55	54	54	610	963	90	90	60	60
Mid-Atlantic	-5	12	9	29	17	53	58	58	677	951	179	179	105	105

Lower Scrap Price Scenario

Region	Old Newsprint Processor ($)	Old Newsprint End-User ($)	Corrugated Processor ($)	Corrugated End-User ($)	Glass Containers Processor ($)	Glass Containers End-User ($)	Steel Cans Processor ($)	Steel Cans End-User ($)	Aluminum Cans Processor ($)	Aluminum Cans End-User ($)	PET Processor ($)	PET End-User ($)	HDPE Processor ($)	HDPE End-User ($)
South	3	4	10	35	20	53	45	45	649	857	80	80	97	97
South-Central	1	16	14	36	6	50	63	63	667	883	100	100	86	86
West	4	30	17	56	19	64	49	49	480	845	81	81	60	60
Northeast	-25	10	-14	21	11	18	54	54	543	993	127	127	80	80
East-Central	2	8	9	24	20	49	57	57	672	810	120	120	80	80
West-Central	1	20	6	20	17	54	50	50	544	861	80	80	60	60
Mid-Atlantic	-14	7	4	24	11	50	46	46	593	901	169	169	80	80

- The unit costs for recycling program components (yard waste collection and processing, curbside collection of other recyclables, and a MRF) were computed given the MWC-specific quantities of recyclables (since costs depend only on throughput).

This database provides most of the information needed to select and assign recycling programs to MWC's and then compute waste diversion and net costs.

The next modeling step was to identify the recycling program that would minimize costs and meet the 25 percent diversion target for each MWC. For this analysis, only one mix of programs to meet the target was focused on: a combination of curbside yard waste collection and curbside collection of other recyclables. The only variation available was the decision to build and operate an MRF or not. As explained earlier, the model assumed that use of an MRF would enable the community to earn higher prices for the scrap material. For each MWC, the model tested whether the higher revenue would be sufficient to cover the cost of the MRF. If so, an MRF was selected; otherwise, no costs were incurred for an MRF.

Once the recycling program was selected, the final step was the calculation of costs or savings for individual MWC's given all of the cost components and cost offsets described in this chapter. Total costs included:

- Recycling program costs;
- Costs for scales to measure compliance with the diversion target; and
- Administrative costs for local governments.

Cost offsets included*:

- Avoided landfilling costs for existing MWC's;
- Downsizing savings for planned MWC's;
- Avoided trash collection costs; and
- Scrap revenues.

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*The total costs offsets were computed by multiplying the unit cost savings or revenue by the number of tons of recyclables collected and actually sold. As a result, the tonnage estimates for recyclables sold and tons diverted from landfills were adjusted downward to take account of waste in with the materials.

Net costs/savings were modeled only for the 171 MWC's that were assumed to incur incremental costs as a result of the federal requirement. The results of the modeling are summarized in the next chapter.

3. RESULTS

This discussion focuses on the 171 MWC's (out of a total population of 280 MWC's) that were assumed to face incremental costs from the federal requirement. The MWC's that were excluded were those located in states with current or impending 25 percent recycling requirements or those with capacities of less than 40 tons per day.

3.1 WASTE DIVERTED

For the 171 MWC's with incremental costs, 11.7 millon tons are collected through the various programs. This accounts for 28.6 percent of the total number of tons of waste generated in the service areas around these MWC's (40.9 million tons of total generation). This total generation estimate includes waste generated by residents within the expanded service areas assumed for existing MWC's. Out of the 11.7 million tons collected, 2.7 million tons is diverted from planned MWC's and 9.0 million tons is diverted from existing units.

While this estimate equals the tonnage collected in recycling programs, it overstates the total quantity of recyclables actually marketed because of contaminants in the recyclables. Scrap revenues and avoided disposal costs were computed after correcting for contamination, since the contaminants are ultimately discarded and not sold.

One additional consideration in the diversion estimates is the 10 percent cap on yard wastes' contribution toward the 25 percent target. We assumed that yard waste programs would collect as much material as possible, even though only a portion of it would count toward the target. As a result, some of the material diverted provides trash collection and disposal cost credit, even though it does not count toward the 25 percent target. The total waste diverted that counts toward the target is only 10 million tons.

3.2 NET COSTS

The net costs (collection and administrative costs minus scrap revenue and other savings) were computed under two different scenarios given varying assumptions about scrap prices and the avoided trash collection and disposal costs. The results summarized in Table 3-1 represent the highest and lowest

TABLE 3-1. COST ESTIMATES FOR MUNICIPAL WASTE COMBUSTOR SOURCE SEPARATION RULE[a]

	Low estimate (Scenario 1) ($)	High estimate (Scenario 2) ($)
Separation costs[b]	668	669
Avoided Disposal		
Landfilling (Existing (MWC's)	(356)	(174)
Downsizing Planned MWC's	(96)	(96)
Trash Collection	(298)	(121)
Scrap Revenues	(263)	(220)
Net Cost (Savings)	(345)	58
Cost (Savings) per ton diverted	(29)	5
Cost (Savings) per ton combusted[c]	(12)	2

[a]Based on 171 MWC's.

[b]Includes collection and processing of matrials and administrative costs.

[c]Total cost divided by tons of MWC throughput after the regulation.

net costs scenarios; Scenario 1 reflects the lowest cost scenarios (because the higher costs offsets are assumed for scrap value, trash collection, and landfill avoided costs) while Scenario 2 reflects the highest cost scenario (because it applies the lower cost offsets).

Separation cost estimates are dominated by collection and processing cost for recyclables, which account for 87 percent of the total. Costs for administration of the program ($84 million annualized) and measuring compliance ($0.6 million annualized) account for the remaining 13 percent of the total. The slight difference between the separation costs in the two scenarios results from the different scrap value assumptions. Changes in scrap revenue may change in the selection of the lower-cost curbside program (with or without an MRF), so the different separation costs reflect a slightly different mix of collection programs in the two scenarios.

The cost savings are distributed across all of the categories shown in Table 3-1. Under Scenario 1 avoided landfilling costs account for the largest share of savings ($356 million annualized or 35 percent), followed by avoided trash collection costs (29 percent), scrap revenues (26 percent), and downsizing credits (10 percent). Total offsets under Scenario 1 are $1,013 million. For Scenario 2, total offsets drop to $611 million and are dominated by scrap revenues (36 percent), avoided landfilling costs (28 percent), avoided trash collection (20 percent), and downsizing credits (16 percent).

The two modeling scenarios demonstrate the sensitivity of the results to the offset assumptions. Scrap revenues do not vary dramatically; the difference between the two scrap scenarios is about $43 million per year. The disposal/collection assumptions do make a substantial difference, however. The alternative assumptions account for a $182 million difference in avoided disposal costs for existing MWC's and a $177 million difference in avoided trash collection costs. Downsizing savings are the same in all scenarios.

The net costs of the two scenarios vary over a large range, from an annualized net cost of $58 million to a savings of $345 million. This range implies that the net effect of the regulation is somewhat uncertain; the cost and savings categories that appear relatively constant across scenarios are also subject to variation since recycling program costs can vary dramatically and scrap prices (as with any commodity prices) can fluctuate wildly. Taking these estimates as an indication of national costs and savings, however, they provide a reasonable bound on the cost consequences of the regulation.

Table 3-1 also shows the net costs (savings) per ton of waste diverted through the program and per ton of waste combusted in the 171 MWC's after the regulation. Results per ton diverted range from a savings of $29 per ton to a cost of $5. The incremental cost/savings per ton of waste burned after the regulation ranges from a savings of $12 per ton combusted to a cost of $2 per ton.

4. LIMITATIONS OF THE ANALYSIS

As with any modeling effort that simulates regulatory responses, the cost results are quite sensitive to certain assumptions. Modeling site-specific responses to the federal source separation requirements is particularly difficult because of the range of local issues that will influence the ultimate reaction of the MWC's. Given a large enough population, however, the estimates of national level cost should be reasonable predictors of the actual outcome. In this analysis, alternative scenarios were introduced to capture some of the uncertainty inherent in computing the costs of source separation programs. Other factors that were not explicitly considered in defining the scenarios may also affect costs; all of these limitations should be considered when interpreting the model results.

4.1 WASTE DATA

- The results are sensitive to the assumption that existing MWC's would comply with the separation requirement by expanding their service areas and diverting the same quantity of waste that they add to their service area. Because of this assumption, revenues from the sale of power are unaffected by the requirement and savings are included for avoided landfilling costs and trash collection costs for the jurisdiction from which the waste is transferred.

- Waste characterization data are assumed to be constant across the United States. No regional differences in waste composition are included in the analysis, which could affect the ability of some communities to reach the 25 percent target and could affect the revenue earned from recycling.

- Data on participation rates and recoverable fractions are based on limited empirical experience. Many factors contribute to participation rates, ranging from climate to socioeconomic and educational levels of the participants. Changes in either of these fractions would affect the ability of communities to reach the 25 percent target and could affect revenue earned from recycling.

- The model results reflect collection costs and savings based on more than the 25 percent requirement. Because of the 10 percent cap on credit provided for yard waste, the actual tons diverted, the collection program throughput, and the cost offsets are based on a higher diversion rate.

The cost estimates are probably the most sensitive to the first limitation. Because tonnage from existing MWC's dominates the diversion estimates, changes in the compliance assumptions for those units could change the cost estimates substantially.

4.2 RECYCLING PROGRAMS AND COSTS

- The data on costs for recycling programs are extremely limited. Empirical data from secondary sources are difficult to verify and may be biased in an unknown direction. Several different issues arise in this context:
  - Programs were chose based on data availability and adequacy, not random selection. As a result, the costs may not be representative of existing programs.
  - The number of cases was limited for all of the programs, so that statistically significant associations with independent variables were difficult to establish. A number of variables probably affect curbside costs, for example, but a significant association is only shown between size and cost.
  - Based on experience with municipal landfill costs, self-reported costs in the literature are probably below actual costs. For community-operated programs in particular, data on full costs are not always available and capital components often go under-reported or unreported.
- The selection of alternative recycling programs is limited in the model. Only a few different styles of programs were examined, while different permutations of these programs and many other program types could provide a more efficient means of collecting and processing recyclables.
- Administrative costs were significant, yet do not reflect any economies of scale. As a result, these costs may be overstated.

Overall, the total cost of the recycling programs is probably understated because of systematic under-reporting of actual program costs. Two other considerations tend to overstate costs, however. First, a more diverse set of recycling program options would allow for some lower-cost response to the regulation, thus decreasing actual compliance costs. Second, administrative costs are overstated, so actual costs would be less. Despite these two corrections, the under-reporting of costs has a more significant effect on the total cost estimate.

4.3 AVOIDED COSTS

4.3.1 Avoided Landfilling Costs

- The disposal cost savings for all existing MWC's is assumed to result from avoided landfilling costs; this implies that additional waste is drawn from landfills near the MWC in order to maintain the current throughput of the MWC. If expansion of the service area were infeasible, waste would have to be diverted from the MWC itself.

- Key areas of uncertainty are the size of landfills from which waste is diverted and the fraction of the landfills' costs that is avoidable.

4.3.2 Downsizing Credits

- Planned MWC's were assumed to downsize in anticipation of the source separation requirement and would avoid the appropriate capital and operating costs associated with a larger unit. If planned MWC's responded as the existing units were modeled (i.e., diverting waste from neighboring jurisdictions), the avoided costs would be different.

4.3.2 Avoided Trash Collection Costs

- Current trash collection costs were assumed constant for all jurisdictions; in fact, differences in demographics and type-of-service across communities would affect current collection charges.

- The avoided collection costs fractions were based on assumptions about landfilling costs. While the magnitude of the estimates appears reasonable, further research into the actual share of costs that could be avoided is necessary.

4.4 SCRAP PRICES

- Scrap prices may move outside of the range defined for a number of reasons. First, in some regions, sudden increases in the quantity of collected scrap may overwhelm demand for the material, driving down prices at least in the short run. Prices may also increase or decrease for several exogenous reasons. Markets for many of these materials are volatile and respond to changes in the underlying market conditions for the primary materials that they replace. As a result, prices for these commodities could change dramatically, independent of the future supply of recyclables.

- Prices quoted are FOB the purchaser and may not reflect actual revenues if the seller must incur significant transportation costs.

- Material collected and processed is assumed to be of sufficient quality and quantity to command the prices quoted. Prices for small programs or for contaminated materials could be well below these estimates or even negative.

4.5 SUMMARY

Because of a lack of data, the analysis is based substantially on national averages for waste data, costs, and most of the cost savings components. While this will introduce errors into the net costs estimates for individual MWC's, on a national basis, the estimates should be indicative of aggregate results once the rule is in place.

On balance, the analysis probably understates the cost of the regulation because reported costs for recycling programs are probably underestimated and avoided disposal costs and are probably overstated. Other issues, such as the magnitude of avoided trash collection costs, would have an uncertain effect on the net cost. The range of costs/savings would remain large, but would shift upward, indicating a higher aggregate cost at one extreme and a smaller aggregate savings at the other extreme.

5. REFERENCES

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8. Draft Economic Analysis, pp. 3-18 to 3-19.

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