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Economic Impact of Air Pollutant Emission Standards for New Municipal Waste Combustors

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Economic Impact of Air Pollutant Emission Standards for New Municipal Waste Combustors

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6-9	41.4 (Present Value of Capital Costs for Reg. Alt. I)	47.4
6-14	676 (PV of Social Capital Costs for Reg. Alt. IV)	679
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Economic Impact of Air Pollutant Emission Standards for New Municipal Waste Combustors

Final Report

August 1989

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CONVERSIONS AND DEFINITIONS

This report uses metric units, as well as acronyms and terms that may not be familiar to all readers. Following is a short guide to conversions and definitions for a selection of the units, acronyms, and terms.

CONVERSIONS

To Approximate	As	Multiply by	Examples from Text
Mg (megagram)	Ton (2,000 lb)	1.1025	45 Mg ≈ 50 tons 225 Mg ≈ 250 tons
g/dscm (grams/dry standard cubic meter)	gr/dscf (grains/dry standard cubic foot)	0.44	0.02 g/dscm ≈ 0.01 gr/dscf 0.18 g/dscm ≈ 0.08 gr/dscf
TJ (terajoule)	10^6Btu (million British Thermal Units)	948	8.54 TJ ≈ 8,100 10^6Btu 34.2 TJ ≈ 32,400 10^6Btu
TJ (terajoule)	MWh (megawatt hours)	278	4.32 TJ ≈ 1,200 MWh 13 TJ ≈ 3,600 MWh
km (kilometer)	mile	0.62	10 km ≈ 5 miles 25 km ≈ 15 miles 50 km ≈ 30 miles 100 km ≈ 60 miles
C (°Celsius)	F (°Fahrenheit)	[F = (9/5) C + 32]	150°C ≈ 300°F 175°C ≈ 350°F 230°C ≈ 450°F

OTHER MEASURES

hectare	1,000 square meters (m^2)
ng	Nanogram–one billionth of a gram
Nm^3	Normal cubic meter (A normal cubic meter is at 0°C, while a standard cubic meter is at 20°C; both at 1 atmosphere of pressure.)
10^3; 10^6	Thousands; Millions

POLLUTANTS

CDD/CDF	Polychlorinated dibenzo-p-dioxins and dibenzofurans
CO	Carbon monoxide
HCl	Hydrogen chloride
PM	Particulate matter
SO_2	Sulfur dioxide

GENERAL ACRONYMS

APCD	Air pollution control device
FBC	Fluidized bed combustion
MSW	Municipal solid waste
MWC	Municipal waste combustor
RDF	Refuse-derived fuel

ECONOMIC TERMS

National enterprise cost	The sum of the regulatory costs incurred by each MWC, discounted and annualized at market interest rates
National social cost	The sum of the regulatory costs incurred by each MWC, discounted and annualized at interest rates reflecting society's opportunity costs for capital and consumption
Net present value (NPV)	The estimated present value (PV) of the offsetting revenue required to cover the full cost of the NSPSs.
Net present cost (NPC)	The sum of PV capital costs and PV of operating costs net of PV of salvage recovery.
1987$	Constant (real) dollars at their fourth quarter 1987 value
Tipping fee	The charge for incinerating or landfilling MSW, usually $/Mg, imposed by MWCs or landfill operators on MSW collectors. Tipping fees, where they are charged, do not reflect the cost of collecting and transporting MSW to the disposal site and often fail to reflect the full cost of incineration or landfilling.
Unit cost	The full cost of incinerating MSW, in $/Mg, after subtracting credits for electricity and steam
WACC	Weighted average cost of capital (See Appendix A)

REGULATORY AND LEGISLATIVE TERMS

Baseline	Conditions that would exist were there to be no new Clean Air Act §111(b) and (d) regulation of MWCs
Guidelines	Clean Air Act §111(d) emission standards for existing sources
Model Plant	A hypothetical MWC representative of a class of MWCs; used to analyze impacts of regulatory alternatives
NSPSs	Clean Air Act §111(b) new source performance standards
RCRA	Resource Conservation and Recovery Act
Regulatory Alternatives	Sets of performance standards and related requirements for controlling emissions; used by EPA to help select the stringency of regulations. (See Tables 5-2 and 5-3.)
RFA	Regulatory Flexibility Act; also regulatory flexibility analysis, a study of the impact of regulations on small entities (businesses, governments, and organizations)

§111(b)	Clean Air Act section governing emission standards for new sources (NSPSs)
§111(d)	Clean Air Act section governing emission standards for existing sources
Subtitle C	RCRA subtitle governing hazardous waste landfills
Subtitle D	RCRA subtitle governing sanitary landfills

ASSUMPTIONS AND CONVENTIONS

Myriad assumptions, analytical conventions, and underlying calculations form the basis for projecting the economic impacts of EPA regulations. This page summarizes the principal assumptions, conventions, and calculated values used in this report. Chapter 9 describes how projected impacts would be different if some of these assumptions, conventions, and values are changed.

- Effective date for the §111(b) NSPS: January 1, 1990
- Affected MWCs: All MWCs placed under construction on or after the effective date
- Date for which impacts are evaluated: January 1, 1995 (This analysis covers MWCs to be placed under construction 1990 through 1994.)
- Lifetimes of physical facilities:
  - MWCs: 30 years after incurring initial compliance costs
  - APCDs: 15 years
- % utilization of daily capacity (There are some exceptions. These percents remain constant over time.):
  - Mass burn: 85%
  - RDF and FBC: 83%
  - Modular: 82%
- Monetary units: Constant (real) 1987 dollars, usually for the 4th quarter
- Capital costs for each MWC and APCD:
  - Incurred only at the outset of operation of the MWC or APCD
  - Amortized over the lifetime of the MWC or APCD when included in annualized costs
- Annual operating costs and revenues for each MWC or APCD:
  - Invariant over the lifetime of the MWC or APCD
  - Proportional to MWC capacity utilization (for analysis purposes when alternative capacity utilization rates are introduced)
- Market discount rates for computing accounting costs:
  - 8% real WACC for private MWCs
  - 4% real municipal revenue bond rate of interest for public MWCs
- Social discount rates for computing social costs:
  - 10% for capital costs
  - 3% for operating costs

CHAPTER 1
INTRODUCTION AND SUMMARY

The U.S. Environmental Protection Agency (EPA) plans to propose New Source Performance Standards (NSPSs) for air emissions from new municipal waste combustors (MWCs) in late 1989.[1] Affected plants include all MWC plants that are placed under construction after regulations are proposed in the *Federal Register*.[2] These regulations will affect the number of plants built and the combustion technology selected. These regulations will also significantly affect the cost of owning and operating these new plants.

This report uses three economic scenarios to examine the economic impact of the five regulatory alternatives under most active consideration by EPA.[3] We order the scenarios to reflect increasing levels of cost-reducing waste management choices as shown in Table 1-1. With the exception of Regulatory Alternative III the regulatory alternatives are ordered to reflect both increasing stringency of air emission limits and broader industry coverage of more stringent limits. As shown in Table 1-1, we provide quantitative estimates of the economic impact of each regulatory alternative under Scenarios I and III. We expect that quantitative results for these two scenarios in most instances bracket the results for Scenario II, had Scenario II impacts been computed.

The economic impacts reported here are based on a wide variety of estimates and assumptions. The following major assumptions frame the analysis:

- In the absence of the NSPSs, emissions from new MWC plants will just meet current federal limits.
- All plants that burn municipal solid waste (MSW), however small the fraction of MSW in the fuel stream, are subject to the NSPSs.
- Affected facilities are those projected for construction over the period 1990-1994.

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1 New Source Performance Standards (NSPSs) covering MWC plants are sometimes referred to as 111(b) Standards because provisions of Section 111(b) of the Clean Air Act require EPA to propose regulations establishing federal standards of performance for new stationary sources that contribute significantly to air pollution that may endanger public health or welfare.

2 Concurrent with the NSPSs, EPA plans to propose a parallel regulation that provides emission guidelines for existing MWCs under the authority granted by Section 111(d) of the Clean Air Act. Another economic impact analysis (EPA, 1989a) addresses the effects of these 111(d) Guidelines.

3 This analysis does not incorporate the impacts of materials separation requirements and nitrogen oxide emission reduction requirements currently being considered under the NSPSs because of their late inclusion in the regulatory structure.

TABLE 1-1. NSPSs ECONOMIC IMPACT SCENARIOS

Regulatory Alternatives	Extent and Stringency of Coverage		Economic Impact Scenarios		
	Small Plant (≤225 Mg/day)	Large Plant (>225 Mg/day)	Scenario I: Baseline Levels of MWC Activity	Scenario II: Cost-Reducing Choices of MWC Technology	Scenario III: Cost-Reducing Choices of Waste Disposal
I	GCPs[a] Moderate PM[b]	GCPs Best PM	#	+/-	#
IIA	GCPs Moderate PM	GCPs Good Acid Gas[c] Best PM	#	+/-	#
IIB	GCPs Good Acid Gas Best PM	GCPs Good Acid Gas Best PM	#	+/-	#
III	GCPs Moderate PM	GCPs Best Acid Gas[d] Best PM	#	+/-	#
IV	GCPs Good Acid Gas Best PM	GCPs Best Acid Gas Best PM	#	+/-	#

[a] Good combustion practices (GCPs) include proper design and operation of the combustor. Exhaust gas temperature control is also included in all alternatives with GCPs.

[b] Particulate matter (PM) control levels are shown in Table 5-2.

[c] Good Acid Gas control reduces emissions through the use of dry sorbent injection.

[d] Best Acid Gas control reduces emissions through the use of spray dryers and fabric filters.

Key: "#" = Quantitative analysis
"+/-" = Qualitative analysis

The first two assumptions tend to boost both the cost and emission reductions attributed to the NSPSs. Under the third assumption, we confine the analysis to plants built in the initial five years of the NSPSs. While the analysis covers the entire 30-year life of these plants, the third assumption still limits cost and emission reduction estimates attributed to the NSPSs to those plants covered during the initial period of regulation.

1.1 COSTS OF REGULATION

Table 1-2 lists the estimated national social costs of these regulatory alternatives under two of the economic scenarios. Under Scenario I we project that roughly 67 plants representing capacity of 15 million Mg per year will be affected. Under Scenario III, the projected number of MWC plants ranges from 64 for Regulatory Alternative I to 49 for Regulatory Alternative IV. The level of MWC capacity also varies with each regulatory alternative—from 14.5 million Mg per year for Regulatory Alternative I to 9.65 million Mg per year for Regulatory Alternative IV.

TABLE 1-2. NSPSs NATIONAL COST IMPACTS (1987 $)

Scenario and Regulatory Alternative	PV of Social Capital Costs ($10^6)[a]	Annualized Social Costs[b] ($10^6/yr)	Annualized Social Costs per Mg MSW[b,d] ($/Mg)	Annualized Enterprise Costs per Mg MSW[c,d] ($/Mg)
Scenario I				
Regulatory Alternative I	37.8	6.41	0.46	0.37
Regulatory Alternative IIA	227	97.2	6.99	6.45
Regulatory Alternative IIB	268	115	7.70	7.10
Regulatory Alternative III	638	150	10.80	9.23
Regulatory Alternative IV	676	168	11.20	9.69
Scenario III				
Regulatory Alternative I	36.9	6.26	0.46	0.37
Regulatory Alternative IIA	150	67.6	6.86	6.35
Regulatory Alternative IIB	185	82.0	7.69	7.11
Regulatory Alternative III	398	93.8	10.60	9.09
Regulatory Alternative IV	430	107	11.10	9.65

[a] Present value of capital costs are based on 2 consecutive, 15-year life cycles for APCD equipment over the 30-year plant life. These assumptions make no difference in the annualized cost impacts (Robson, 1989).

[b] Annualized social costs are the sum of capital costs, annualized at *10 percent*, and annual operating costs.

[c] Annualized public enterprise costs are the sum of capital costs, annualized at *4 percent*, and annual operating costs.

[d] Computed by dividing total annualized cost by the estimated amount of MSW processed per year.

Estimated annualized social costs of the NSPSs (exclusive of the cost of building or controlling emissions from substitute landfills) increase substantially with the scope and stringency of regulatory alternatives. The large magnitudes result from both the substantial cost of installing and operating additional control equipment on any individual plant and from our baseline projection and scenario projections of the number of plants affected.

As shown in Table 1-2, moving from Scenario I to Scenario III under Regulatory Alternative I results in a 2.3 percent reduction in total annualized social cost and a 2.4 percent reduction in social capital cost. This reduction results from our factoring into the analysis the projected replacement of some of the baseline MWC plants with new landfills because of the additional cost of the MWC plants under the regulations. As the regulatory alternatives become more stringent the percent reduction in costs from Scenario I to Scenario III increases. Moving from Scenario I to Scenario III under Regulatory Alternative IV results in a 36.3 percent reduction in total annualized social cost and a 36.4 percent reduction in social capital costs due to the increasing number of MWC plants that are replaced with new landfill capacity. Note again, however, that the cost of control for Scenario III do not reflect the cost of building or controlling emissions at the landfills that replace some of the affected MWCs.

The capital cost reported in Table 1-2 represents the estimated purchase and installation cost of capital equipment consistent with the NSPSs. About two-thirds of this capital cost represents the "first cost" of the air pollution control devices (APCDs); the other third represents the present value of the capital and installation cost when replacing the original APCDs after 15 years. These expenditures can be amortized over a 30-year operating life and have therefore been included in the annualized cost data. The capital costs of APCDs, however, also represent a substantial initial expense. Because APCDs represent from 5.1 to 22.3 percent of plant capital cost, they possibly increase the financial risk associated with building a MWC plant. For comparison, in 1986 the government enterprise expenditure for fixed capital for air pollution control (primarily for control of municipally owned power plants) was $330 million (1987 dollars) and the capital cost for all solid waste collection and disposal by local government was $1,060 million (1987 dollars) (Farber and Rutledge, 1988).

Table 1-2 also presents the average cost per Mg of waste (annualized cost divided by the amount of MSW processed by affected plants). Such measures are often referred to as costs per unit of waste disposed, or "unit costs." The unit social cost is based on the social costs of the regulation: the cost seen from a social, opportunity cost perspective. The unit enterprise cost is based on the enterprise cost of the regulation: the cost as seen in the accounts of the affected entities, in this case primarily municipalities or public authorities. Because of the difference in the basis for measurement, the unit social costs are about 8 to 24 percent greater than unit enterprise costs. The unit costs increase substantially with the regulatory alternatives, indicating the much higher average costs associated with the broader scope and more stringent controls of the higher regulatory alternatives.

To help put these unit costs in rough perspective, the average price for disposing of a Mg of waste at a MWC that charged a "tipping fee" (a fee paid by the trash hauler for the privilege of dumping or tipping trash at the MWC plant) in 1988 was $42.70 (1987 dollars). On this basis, the unit enterprise cost increases for MWC plants as a whole would range from 0.86 to 23 percent under Scenarios I and III.

1.2 EMISSION REDUCTIONS

The NSPSs will reduce emissions of a variety of air pollutants. This report provides estimates of national emission reductions for CDD/CDF, CO, PM, SO_2, HCl, Pb, and ash for MWC plants. The baseline national emissions and emission reductions for Scenario I and emission reductions for Scenario III are shown in Table 1-3. Baseline emissions for Scenario III are not reported because the replacement of planned MWC plants by landfills varies with each regulatory alternative. Our convention for computing emission reductions under Scenario III is the difference between baseline emissions from MWC plants under a given regulatory alternative and the emissions after these plants are controlled to meet the NSPSs for that regulatory alternative.

Under Scenario III, because there are fewer MWC plants, emission reductions are lower than under the other Scenarios. As noted above, that qualitative result should be interpreted carefully because it doesn't account for air emissions from the landfills whose selection can be attributed to the NSPSs. To estimate emission reductions for Scenario III comprehensively, we need to know how many affected MWC plants would be replaced by non-combustion disposal technologies and what air pollutants these substituted alternatives would emit. Without such data, we can't even project whether national emissions increase or decrease with the NSPSs in Scenario III.

TABLE 1-3. NSPSs NATIONAL BASELINE EMISSIONS AND EMISSIONS REDUCTIONS (Mg per yr.)

Scenario and Regulatory Alternative	CDD/CDF	CO	PM	SO_2	HCl	Pb	Ash[b]
Scenario I							
Baseline Emissions	0.0152	5,470	7,540	42,000	49,300	127	3,700,000
Emissions Reductions							
Regulatory Alternative I	0	0	5,220	0	0	88.5	-154,000
Regulatory Alternative IIA	0.0107	0	5,220	18,300	36,700	108	-383,000
Regulatory Alternative IIB	0.0115	0	5,960	19,300	39,500	124	-401,000
Regulatory Alternative III	0.0139	0	5,220	35,400	44,400	108	-314,000
Regulatory Alternative IV	0.0146	0	5,960	36,400	47,200	124	-332,000
Scenario III							
Baseline Emissions[a]	———	——	———	———	———	——	———
Emissions Reductions							
Regulatory Alternative I	0	0	5,120	0	0	86.3	-138,000
Regulatory Alternative IIA	0.00781	0	3,440	13,700	25,700	77.9	-308,000
Regulatory Alternative IIB	0.00841	0	4,040	14,500	27,900	90.3	-322,000
Regulatory Alternative III	0.00916	0	2,980	22,400	27,700	68.6	-232,000
Regulatory Alternative IV	0.00974	0	3,550	23,100	29,900	81.6	-246,000

[a] Scenario III baseline emissions vary with each regulatory alternative because the level of total waste flows handled by MWC varies with each regulatory alternative under Scenario III.

[b] Includes bottom ash and fly ash with some residual quench water. Negative values reflect increases in ash emissions relative to the baseline.

KEY: polychlorinated dibenzo-*p*-dioxins and dibenzofurans (CDD/CDF), carbon monoxide (CO), particulate matter (PM), sulfur dioxide (SO_2), hydrogen chloride (HCl), and lead (Pb).

1.3 DISTRIBUTION OF ECONOMIC IMPACTS

Because of the localized nature of solid waste management markets and institutions, it is difficult to generalize about the economic sectors that would be affected by the NSPSs and about the magnitudes of those impacts. This analysis, therefore, examines in some detail the economic impacts on three economic sectors: affected MWC plants, households served by MWC plants, and government units that own and operate MWC plants.

1.3.1 MWC Plants and Technologies

The regulatory alternatives considered by EPA distinguish between large and small plants, varying the emission requirements and associated controls for the different size plants within the same regulatory alternative. At the same time, differences in design capacity, technology, etc. contribute to variations between MWC plants in the cost of controlling at the same level. These differences in cost can be seen in the data of Table 1-4 for Scenario I, Regulatory Alternative IV. This table presents estimated control costs for 12 model plants used in the analysis. It shows that the absolute magnitude of capital and operating costs, as well as their relative magnitudes, vary considerably by the size and type of plant.

TABLE 1-4. ENTERPRISE COSTS OF CONTROL FOR PUBLICLY OWNED NSPSs MODEL PLANTS (1987$)[a]: SCENARIO I, REGULATORY ALTERNATIVE IV

Model Plant #	Model Plant Description[b]	Model Plant Capacity (Mg/day)	PV of Capital Cost[c] ($10^3)	Total Annualized Cost[d] ($10^3/yr)	Cost of Control per Mg[e] ($/Mg)
1	MB/WW (small)	180	1,710	639	16.90
2	MB/WW (mid-size)	730	13,800	2,250	10.00
3	MB/WW (large)	2,040	28,500	4,910	7.78
4	MB/REF	450	13,700	2,100	15.00
5	MB/RC	950	17,800	2,940	9.97
6	RDF	1,810	30,600	5,400	9.86
7	RDF/CF	1,810	30,600	3,240	11.90
8	MOD/EA	220	1,960	573	8.83
9	MOD/SA (small)	45	2,180	448	47.40
10	MOD/SA (mid-size)	90	1,960	460	17.00
11	FBC/BB	820	13,300	2,110	8.54
12	FBC/CB	820	13,300	2,110	8.54

[a] Control costs are costs over the baseline model plant costs of Chapter 3. These costs are incurred to meet the emission requirements of the NSPSs.

[b] Definition of terms used to describe model plants contained in Table 3-2.

[c] Present value of capital costs are based on 2 consecutive, 15-year life cycles for APCD equipment over the 30-year plant life.

[d] Total annualized costs based on a 30-year facility life, 15-year APCD equipment life, and a real discount rate of 4 percent.

[e] Computed by dividing total annualized cost by the estimated amount of MSW processed per year at the model plant.

The unit enterprise cost data of the table show these costs after adjustment for the size of the MWC. They range from $7.78, for a large mass burn waterwall plant, to over $47 per Mg for a small modular plant. In general, for plants with non-zero control costs, the smaller the MWC plant, the greater the economic impact, especially under Regulatory Alternatives IIB and IV in which smaller plants must meet more stringent emission requirements than under the other regulatory alternatives. Since modular plants are generally the most cost-competitive small plants, modular technology will be most affected by the NSPSs.

Table 1-5 provides a broader picture of plant impacts across regulatory alternatives. These data show that a wide range of unit enterprise costs apply to model plants. While recognizing that the tipping fee is as much an administrative convention as it is a measure of cost, data values at the high end of the unit enterprise cost range are from 35 to 110 percent of the average tipping fee reported in 1988. Disregarding zero values, the low end values range from 9 to 21 percent of the average 1988 tipping fee.

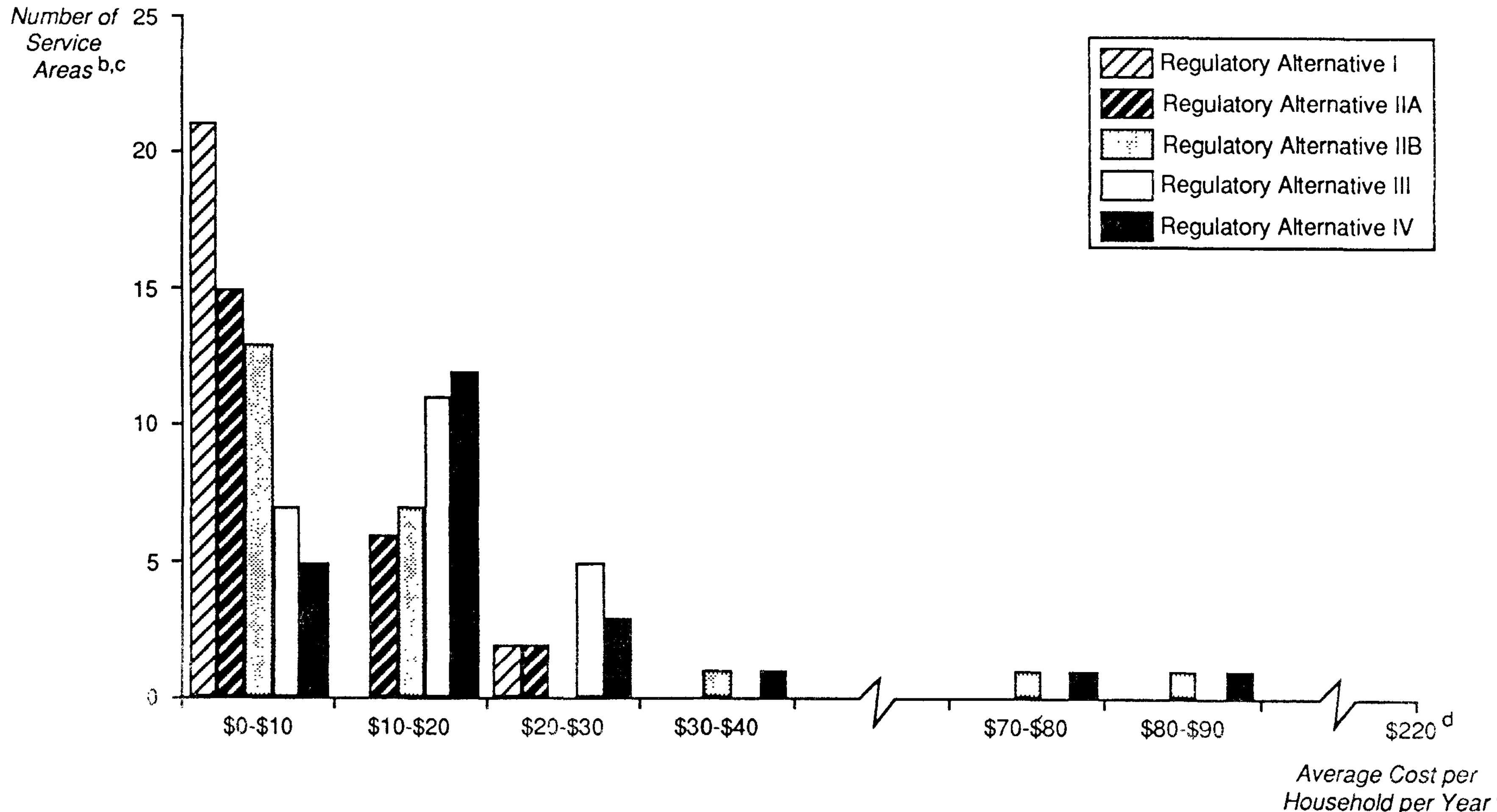
TABLE 1-5. ENTERPRISE COST OF CONTROL PER Mg FOR PUBLICLY OWNED NSPSs MODEL PLANTS UNDER SCENARIO I (1987 $)[a]

	MWC Plant Capacity	
	Small— ≤225 Mg/day ($/Mg)	Large— >225 Mg/day ($/Mg)
Regulatory Alternative I	0.00-12.70	0.00-0.75
Regulatory Alternative IIA	0.00-12.70	3.88-9.38
Regulatory Alternative IIB	8.83-47.40	3.88-9.38
Regulatory Alternative III	0.00-12.70	7.78-15.00
Regulatory Alternative IV	8.83-47.40	7.78-15.00

[a] Cost per Mg based on cash flow analyses of publicly owned plants described in Chapter 3.

1.3.2 Households

By matching Census of Governments and Census of Population data for particular MWC sites with model plant cost data, we obtained estimates of the economic impact of the regulatory alternatives on households in the MWC service areas that would likely have new plants. In most cases, the cost per household is estimated to be under $30 per year and only in a few cases is it estimated to be as high as $90 per year. The distribution of these costs by regulatory alternative is shown in Figure 1-1.



[a] Costs refer to control costs only; no baseline costs are included.

[b] Service areas with less than 2,500 total population were not included in the sample because census data for these service areas were not available.

[c] Service areas with implicit capacity utilization less than 40 percent for modular plants, less than 60 percent for other technologies, or greater than 400 percent for all technologies were not included in the sample. See text in Chapter 8 for discussion.

[d] Household impacts were defined as "severe" if average cost exceeds $220 per household per year.

Figure 1-1. Distribution of Household Impacts Under NSPSs by Number of Service Areas and Regulatory Alternative: Index 1

While there is a great deal of variation in a household's solid waste disposal collection and disposal budget, it probably ranges from $100 to $200 per year. Many of the costs estimated in this analysis would represent a significant (greater than ten percent) increase in that budget if passed on to households in their entirety. Even so, because the household budget for solid waste collection and disposal is so low, these costs do not exceed the threshold criteria for "severe" impacts recently applied to another regulation affecting solid waste disposal (EPA, 1988b).

1.3.3 Government Units

The NSPSs increase the cost of MWC plants by different amounts depending on the technology, size, and emission controls of a given plant. Public entities that plan to build plants for which the shift is largest bear a larger share of the regulatory cost than those for which the shift is smaller. A government unit's economic impact, then, depends on the particular MWC plant they build, or are served by, respectively, in conjunction with the regulatory alternative ultimately selected as the basis for the NSPSs. As in the case of households, this government unit impact analysis matches communities with cost impacts for particular MWC plants. Because of data limitations, we made assumptions that, on the whole, amplified the impacts while at the same time limited the number of matches that could be made. We applied several criteria for measuring the severity of impacts on government units. For all but one of these criteria, the impacts were not found to be severe. For the remaining criterion, 9 of the 17 communities examined showed severe impacts. We therefore made follow-up phone calls to these communities and found that the assumptions we used to estimate the population served by the MWC did indeed amplify the impacts. In most cases, the financial base in our analysis was underestimated. For example, the combustor plant located in Dayton, Ohio, serves Montgomery County as well as other nearby counties and municipalities which may dispose of waste at the combustor plant for a fee. When we corrected the data to better reflect actual site conditions, the impact measures were no longer severe for these communities.

CHAPTER 2
DEMAND CONDITIONS

The demand for municipal waste combustion is derived from the demand for services that collect and dispose of the large volume and variety of wastes we produce each year. Most, but not all, of the material burned at municipal waste combustors (MWCs) is classified as municipal solid waste (MSW). About 130 million Mg of MSW was generated in 1986 (Franklin Associates, Ltd., 1988). This represents an annual average of one-half Mg per capita based on the middle-series projection of total population in *Statistical Abstract of the U.S.* (U.S. Department of Commerce, 1987).

MSW consists of all the major materials used in the modern industrial state. Table 2-1 presents the estimated quantities and shares of these materials. Paper and paperboard products comprise over 35 percent of the total. Glass, metals and plastics are each about one-fifth to one-quarter of the paper and paperboard amount. Yard waste (e.g., grass clippings, tree trimmings, and leaves) represent the second largest portion of MSW—about 20 percent.

2.1 GENERATORS

Generators of MSW demand services that collect and dispose of MSW. These generators provide most of the demand, often a "derived demand," for MWC services. As shown in Figure 2-1, the demand for MSW collection and disposal services can be classified into four broad source categories:

- Residential: Waste from single- and multiple-family homes.
- Commercial: Waste from retail stores, shopping centers, office buildings, restaurants, hotels, airports, wholesalers, auto garages, and other commercial establishments.
- Industrial: Waste such as corrugated boxes and other packaging, cafeteria waste, and paper towels from factories or other industrial buildings. This term does not include waste from industrial processes, whether hazardous or nonhazardous.
- Other: Waste from public works such as street sweepings and tree and brush trimmings and institutional waste from schools and colleges, hospitals, prisons, and similar public or quasi-public buildings. Infectious and hazardous waste from these types of facilities are managed separately from MSW.

Households are the primary direct source of MSW, followed by the commercial sector. On average, each U.S. household directly generated 0.79 Mg of solid waste in 1986. The commercial, industrial, and other sectors each directly generate smaller portions of MSW than households (see Figure 2-1). In particular, the industrial sector manages most of its own solid

TABLE 2-1. MATERIALS IN THE MUNICIPAL WASTE STREAM, 1986

Materials	10^6 Mg	Percent
Paper and Paperboard	45.6	35.6
Glass	10.7	8.4
Metals	11.5	8.9
Plastics	9.4	7.3
Rubber and Leather	3.5	2.8
Textiles	2.5	2.0
Wood	5.3	4.1
Food Wastes	11.4	8.9
Yard Wastes	25.8	20.1
Miscellaneous Wastes	2.5	1.8
TOTAL	128.1	100.0

Source: Franklin Associates Ltd., 1988. *Characterization of Municipal Solid Waste in the United States, 1960 to 2000.* Final report prepared for U.S. Environmental Protection Agency.

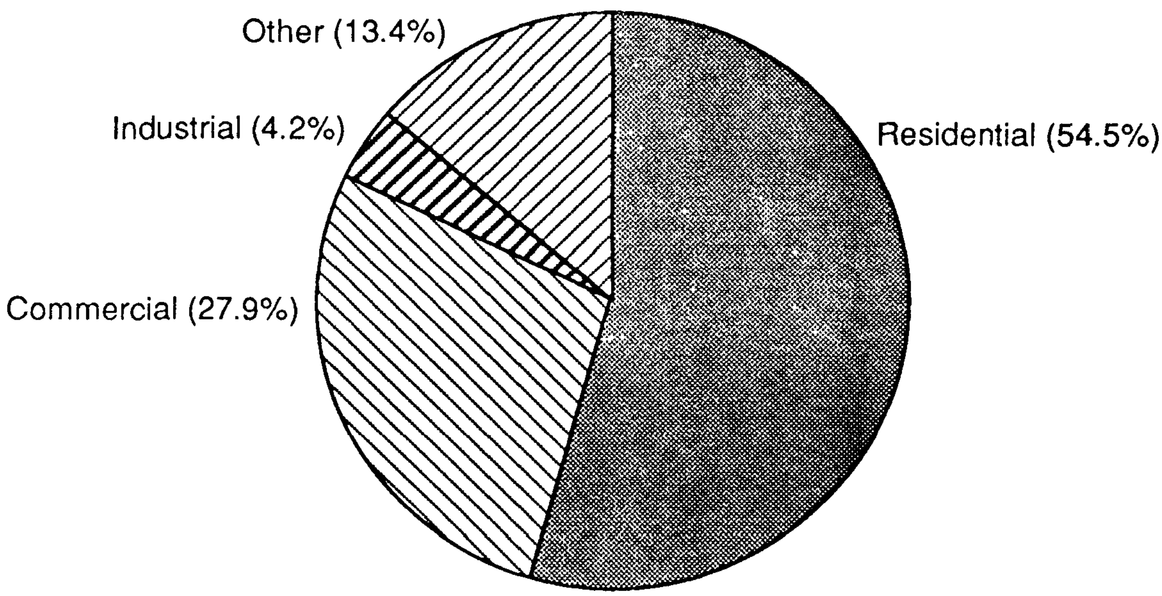


Figure 2-1. Sources of Municipal Solid Waste, 1986

Source: U.S. Environmental Protection Agency. 1988b. *National Survey of Solid Waste (Municipal) Landfill Facilities.* Final Report. Prepared by Westat, Inc. EPA/68-01-7359. Table 7-3.

residuals, whether MSW or industrial process wastes, by either recycling, reuse, or self disposal. Thus, direct generation of MSW by industry accounts for only a small share of the MSW flows, although some industrial process wastes do end up being collected and disposed of along with MSW.

As shown by Bingham et al. (1976), through derived demand relationships, households and other components of "final demand" (business spending on plants and equipment, government spending, and exports) indirectly affect the amounts and composition of residuals discarded to the environment, including solid wastes directly generated by other sectors. For example, when food items are shipped to the supermarket in cardboard boxes, the boxes are unpacked and items shelved at the store. When the shipping containers are discarded to the MSW system, the household has indirectly contributed to the amount and composition of MSW. Although the waste is attributed to the commercial sector, the store directly generated MSW as a results of the household's demand for food.

Little empirical evidence is available about the factors that affect waste generation rates. However, without substantial changes in market conditions or policies that promote more recycling and the use of less residual-intensive production, packaging, and consumption methods, increases in economic activity and in the population indicate that MSW will increase in the future. Franklin Associates (1988) estimates that MSW will increase at an annual rate of approximately 1.5 percent over the 1984-2000 period. This growth rate is slightly more than the population growth rate, indicating an increase in expected per-capita waste generation. A recent Frost and Sullivan report (*Coal and Synfuels Technology*, July 25, 1988) estimates that future MSW generation will be proportional to population growth.

2.2 GENERATOR BEHAVIOR

The responsiveness of the quantity of MSW generated by each generator is important because regulatory actions may change the conditions under which households and firms make MSW generation and collection choices. Little empirical information is available regarding these choices. However, some conjectures are advanced below. In each case a demand relationship is hypothesized and used to organize the subsequent discussions.

2.2.1 Household Demand

Final consumption purchases (e.g., food items) and household production activities (e.g., yard care) result in the generation of MSW. Since these wastes do not provide the household with utility they are an economic "bad" whose collection and removal is a service of value to the household. A household may be viewed as having a demand for solid waste collection and disposal services, Q_c, just as it has a demand for food and other consumer goods:

$$Q_c = f_1(Y, P_c, S, C) \tag{2.1}$$

where

Y = household income,

P_c = price of waste collection and disposal services,

S = service conditions (e.g., frequency of collection and site of collection, degree of waste separation required, materials accepted), and

C = cost of self-management (e.g., recycling, incinerating, burying, littering).

Household income changes affect the household's demand for MSW collection and disposal services. Increases in the household's income increase consumption spending; however, because of savings, the relationship is not one-for-one. These consumption increases include increases for commodities that generate solid wastes. Solid waste collection and disposal is likely a normal good—as income increases, all other arguments in the demand function held constant, the demand for solid waste collection and disposal services increases (see Figure 2-2). Wertz (1976) has argued that the income elasticity of demand for collection and disposal services, $(\partial Q_c/Q_c)/(\partial Y/Y)$, is likely to be positive, but small. Goddard (1975), while noting

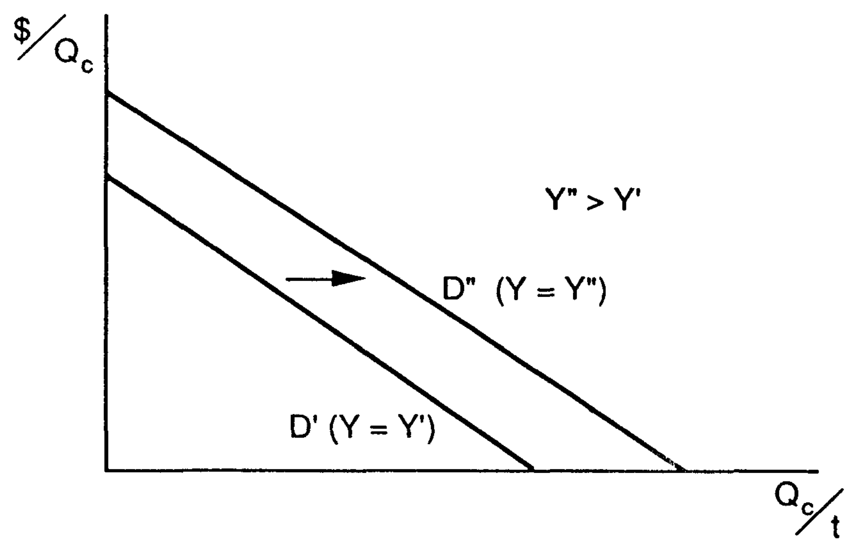


Figure 2-2. Effect of Income Changes on Household Demand for MSW Collection and Disposal Services

serious data and methodology problems in a study of demand for waste collection in Chicago, reports an income elasticity of demand estimate of 0.4.

In most communities today, MSW collection and disposal services are financed by general tax revenues. If increased costs for these services result in increased tax rates, disposable household income will be reduced. Given a positive income elasticity of demand for waste collection and disposal services, this would, in turn, reduce MSW generation. Because both the income elasticity and the cost of MSW collection and disposal as a share of all taxes are small, however, this effect is unlikely to be significant.

The relationship between quantity demanded and price is an inverse one—increases in the price for MSW collection reduce the quantity demanded of these services. This inverse relationship has been empirically demonstrated for a large variety of commodities; MSW collection and disposal services should not be an exception to these findings. However, it is difficult to demonstrate this relationship for MSW collection and disposal services and estimate the numerical relationship because of

- the variety of MSW collection service arrangements,
- the absence of MSW collection pricing on a per-unit-of-service basis, and
- the lack of adequate micro data on household waste generation rates.

As noted above, in most communities today there is no price mechanism through which changes in the cost of MSW collection and disposal services provide incentives to households to adjust their use of collection and disposal services. When households are not charged, the price of collection and disposal services is zero and the quantity demanded is Q_c^1 in Figure 2-3. In some communities households are charged a flat fee per week or month for a specified service (e.g., solid waste collected from four containers twice weekly). At best, this provides a weak link between the fee (or price of service) and the amount of MSW generated since the fee does not vary with the amount of waste generated by any given household.

In a few communities, such as Seattle, households are charged on a per-container basis. In such instances the linkage between price and the quantity of waste generated is strengthened. Increasing in the price per container certainly encourages households to find ways to reduce the number of containers used and likely has an effect on the amount of waste generated. As the containers become small relative to the amount of waste generated, the household demand begins to resemble that depicted in Figure 2-3. For a price change from P_c^2 to P_c^3, the quantity of MSW generated declines from Q_c^2 to Q_c^3.

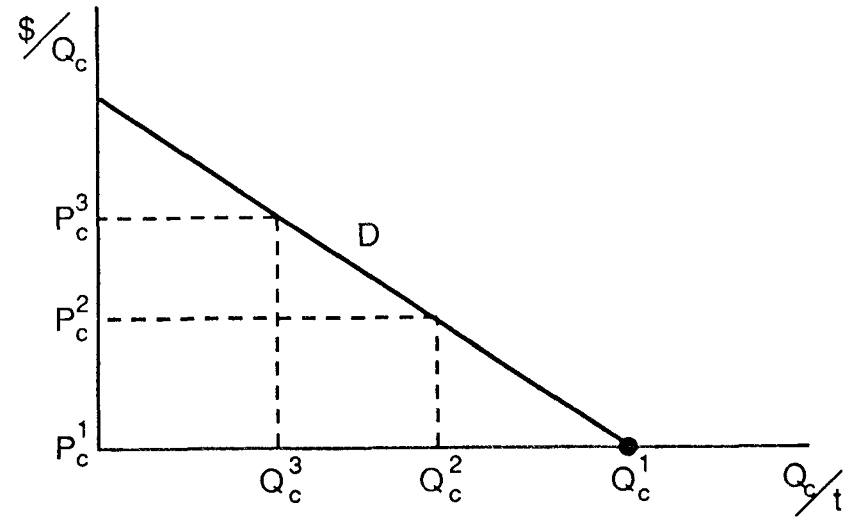


Figure 2-3. Effect of Collection and Disposal Price Changes on the Household Demand for MSW Collection and Disposal Services

In communities where price provides an incentive to adjust the amount of MSW generated, the household price elasticity of demand for MSW collection and disposal services $(\partial Q_c/Q_c)/(\partial P_c/P_c)$ is negative but the magnitude is likely to be small. Goddard (1975) reports on a 1972 cross-section study of California communities that charged their citizens different flat rates for MSW collection. While again noting data and methodological difficulties in the study, Goddard reports that the researchers estimated statistically significant coefficients that are akin to price elasticities for two forms of the demand equation. The point estimates of these values were -0.7 and -0.5 with 95 percent confidence limits of -0.5 to -1.0 and -0.3 to -0.8, respectively.

Part of the household's costs of MSW collection and disposal services is the household's implicit cost of storing the waste before it is collected, sorting materials as required by the collector, and moving the wastes to the place of collection (e.g., front yard, back yard). Wertz (1976) cites evidence that the frequency of service elasticity $(\partial Q_c/Q_c)/(\partial S/S)$ is likely to be positive and high: as collection frequency increases, or collection site convenience is improved, collection demand increases.

Increasing the inconvenience of disposing of certain wastes (e.g., aluminum containers) by requiring that they be sorted is likely to reduce generation of those wastes. Households may substitute products that produce waste that needs to be sorted with ones that do not; the net effect on total waste generation is uncertain. We have not found any empirically based estimates of the effect of different sorting requirements or opportunities on total waste generation.

Households may self-manage the solid wastes they do generate through recycling, burying, incinerating, compacting, discarding to the sewer system or to others' collection systems, or by littering. Further, they may transport their wastes directly to the disposal site. These activities have costs to the household, either explicit or implicit, and thus by themselves reduce the household's welfare. However, these activities also offset the costs of MSW collection. Increases in the costs for any self-management option are expected to lead to greater use of other such options or to greater use of the MSW collection and disposal services provided by other parties.

2.2.2 Firm Demand

The firm's derived demand, Q_c, for MSW collection and disposal services is

$$Q_c = f_2(P_c, P_x, S, C) \tag{2.2}$$

where

P_x = price of the firm's output and, other terms are as defined above.

The price elasticity of demand, $(\partial Q_c/Q_c) / (\partial P_c/P_c)$, or simply e_c, for collection and disposal services can be shown to equal

$$e_c = v_c\,(h_x + s_c) \tag{2.3}$$

where

v_c = ratio of collection and disposal cost to all costs of production,

h_x = demand elasticity for the output x,

s_c = Allen elasticity of substitution between waste collection and disposal services and all other inputs in the production of output x.[1]

Firms' payments for municipal waste collection and disposal services, v_c, likely comprise a small share of production costs. Product demand elasticities, h_x, vary from commodity to commodity but typically range from -0.5 to -5.0. The elasticity of substitution between waste

[1] The Allen elasticity of substitution is the ratio of the output-constant cross elasticity of demand for the factors of production (waste collection and other inputs to production) and the v_c of waste collection.

collection and all other inputs is positive, but there are no estimates of this value. However, even if firms have substantial opportunities to make solid waste reducing process changes, the associated elasticity of substitution is weighted by v_c, a value much less than one. Thus, in many cases, we expect the product $v_c s_c$ to be fairly low. This implies an inelastic demand by firms for MSW collection and disposal services; that is, a price elasticity of demand less than 1 in absolute value.

In summary, because of current MSW collection and disposal service financing methods and demand relationships it seems unlikely that NSPSs affecting the costs of MWC will significantly influence the overall demand for municipal waste collection and disposal services, the composition of waste, or the expected increases in MSW generation over time. Even in cases where increased costs are passed on to waste generators in the form of higher prices for waste collection and disposal services, price inelasticity will moderate the impact of price changes on the quantities of waste generated. Most of the important effects are expected in the demand for disposal services per se, particularly the demand for MWC disposal services, and in the supply side of the market for these disposal services.

2.3 WASTE DISPOSAL SERVICES DEMAND

It is sometimes helpful to think of waste collection as distinct from waste disposal. Given such a distinction, waste collectors have a demand for waste disposal services in addition to their demand for labor, equipment, and other inputs used in the production of the service they provide. The change in this derived demand in response to changes in the cost of disposal can be analyzed through use of the general elasticity of demand expression introduced above. This expression, adapted to examine the determinants of the elasticity of demand for waste disposal, e_d, is written below.

$$e_d = v_d (h_c + s_d) \qquad (2.4)$$

where

v_d = ratio of the cost of disposal services to the total cost of waste collection and disposal (the cost share),

h_c = demand elasticity for collection and disposal services,

s_d = Allen elasticity of substitution between disposal services and all other inputs to waste collection and disposal.

While historically the cost share of disposal has been a small share of waste collection service costs, it has been rising very rapidly (Glebs, 1988). A recent report estimates the cost share of disposal to now be in the neighborhood of 50 percent (Morris, 1987). Consequently, the share of collection costs represented by disposal services is probably large. The elasticity of demand for collection services, as argued above, is likely to be inelastic (small) and, depending on institutional conditions, virtually zero in some cases. Also, since every unit of collected wastes must be disposed of, it is difficult to credit the notion of a large elasticity of substitution between disposal services and other inputs to production of waste collection and disposal. Thus, while the v_d coefficient in the elasticity expression may be large, the two terms inside the parentheses are small, suggesting a moderate to small elasticity of demand for waste disposal services. Anything short of a major increase in the price of disposal services is unlikely to result in much of a change in the demand for those services.

Not all waste collected is disposed of in the same fashion. While households and firms demand collection and disposal services, the organizations that collect the waste may be able to choose among a variety of locations and technologies for disposing of MSW. These collectors may be part of an integrated system of MSW management services, private collectors, or generators that self-collect. They may be subject to a very different set of legal, institutional, and market conditions. Even so, we can further decompose the analysis of waste disposal services demand and further adapt the general derived demand relationship introduced above to examine the determinants of the elasticity of demand for MWC disposal services, e_{mwc}, in particular.

$$e_{mwc} = v_{mwc} (h_d + s_{mwc}) \qquad (2.5)$$

where

v_{mwc} = the ratio of MWC disposal services to the total cost of disposal (the cost share),

h_d = demand elasticity for disposal services,

s_{mwc} = Allen elasticity of substitution between MWC disposal services and all other inputs to waste disposal.

For this equation for demand elasticity, the cost share will likely vary with the local MSW management area in question and, as argued above, the elasticity of demand for waste disposal services is likely to be moderate to low. The Allen elasticity of substitution, s_{mwc}, may well be quite high if landfills, recycling centers, etc., provide essentially the same disposal services at a similar price. The total effect of these influences on the demand for MWC disposal services is uncertain, but conditions may well exist where demand is elastic and the increased cost imposed by the NSPSs could change the mix of MSW disposal technologies, if not total waste generation or disposal.

CHAPTER 3
SUPPLY CONDITIONS

Solid waste management today often consists of a set of interrelated activities for the collection and transport, processing, and disposal of solid wastes. The material flows associated with most of these activities are illustrated in Figure 3-1. In light of both the preceding demand analysis and the regulation in question, this discussion of supply conditions focuses on the supply of municipal waste combustion and landfilling disposal services. Also examined, but to a lesser extent, are waste recycling and transportation services.[1]

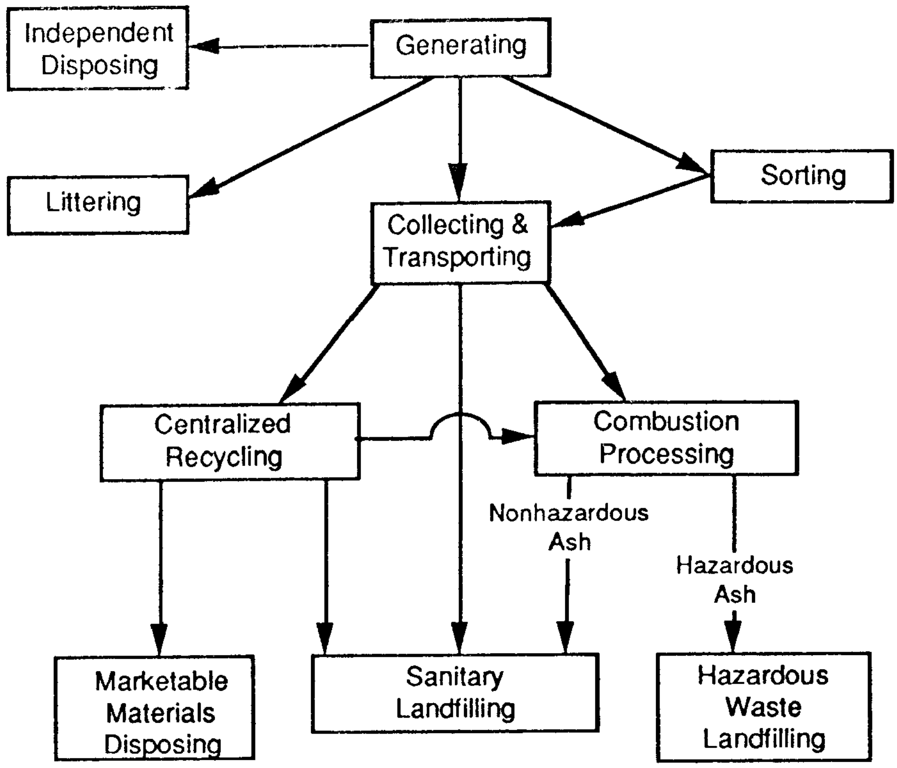


Figure 3-1. Solid Waste Management Options

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[1] Not included in Figure 3-1 are strategies relating to the design, manufacturing, packaging, and use of products so as to reduce the quantity and toxicity of solid waste, especially MSW. These "source reduction" activities are technically related to the substitution options that households and firms would consider if there were an effective price mechanism that provided an incentive for reductions in solid waste generation. While source reduction is part of EPA's national strategy for solid waste (EPA, 1989d), it probably will not be pursued under authority of the Clean Air Act. Consequently, we don't address source reduction in this report. To the extent that source reduction may alter the cost-effectiveness of the air pollution control devices (APCDs) considered in this report, this exclusion is a shortcoming.

Landfilling is the predominant method of solid waste disposal in the U.S. today. In 1986 approximately 80 percent of all MSW was directly landfilled, 10 percent recycled, and 10 percent combusted. The percentage of recycled or combusted discards has been growing since 1960, however, and these technologies are expected to have an even greater impact on MSW disposal in the future (Franklin Associates, Ltd., 1988).

3.1 PRODUCTION PROCESSES

Understanding the production processes involved in solid waste management is the first step toward understanding its economics. First we examine the production functions. For each process involved in the management of MSW, production functions describing input and output relationships can be written in the form

$$Q_1,...,Q_m = f(X_1,...,X_n), \tag{3.1}$$

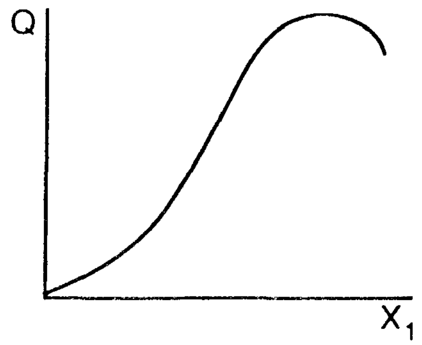
where $Q_1,...,Q_m$ represent outputs 1...m produced and $X_1,...,X_n$ represent inputs 1...n consumed during the production period. Recognizing multiple outputs is particularly important in this analysis because many combustors both dispose of waste (into the air with a 20 to 30 percent solid waste residual) and produce energy.

In a simple setting this relationship reduces to one output and two inputs:

$$Q_1 = f(X_1, X_2). \tag{3.2}$$

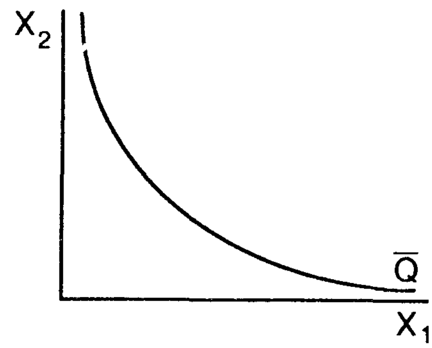
These production relationships may be examined from two perspectives—the operating decision and the investment decision. For simplification the analysis assumes that existing firms concern themselves with the operating decision in the short run, whereas new firms are faced with the investment decision along with the subsequent operating decision. Existing firms decide on the operating rate within the constraint of the fixed resource (Figure 3-2a). Owners of the new firm make decisions regarding scale and resource substitution without the constraint of a fixed resource (Figure 3-2b). This distinction, too, is important in this analysis since combustor managers will chose between the best means of operating the existing plant (an operating decision) and the best new combustor investment (an investment decision).

Figure 3-2a illustrates the choices involved in operating decisions when one of the inputs, X_2, is fixed. The firm must choose the optimum operating rate, Q_n, and input rate, X_1. The specific relationships between inputs and outputs is an empirical issue. Figure 3-2a illustrates a situation where output increases rapidly as additional X_1 is added over some range of input.



$Q = f(X_1, \bar{X}_{other})$

Figure 3-2a.
Operating Decisions: Choices Involved with at Least One Fixed Input



$\bar{Q} = f(X_1, X_2)$

Figure 3-2b.
Investment Decisions: Choices Involved with No Fixed Inputs

However, the ability of additional X_1 to generate additional output deteriorates as more X_1 is used. Finally, output reaches a maximum level. Beyond this point, additional X_1 decreases output.

Figure 3-2b illustrates the choices involved when both inputs are variable, as is the case with the investment decision. The output rate $\bar{Q}$ shown is constant. The curve shows the alternative combinations of inputs X_1 and X_2 that produce that rate of output.

We now use the concept of the production function to examine the major components of MSW management associated with air emission NSPSs for MWCs: combustion, landfilling, collection and transportation, and recycling.

3.1.1 Combustion

Municipal waste combustion (MWC) is the process of reducing the volume of MSW through incineration. Because MWC reduces waste volume by as much as 70 to 90 percent, this method of waste management has the potential to significantly reduce the need for landfills.

Industry Conditions

Combustion was once the principal way of disposing of MSW, especially in the metropolitan areas of the U.S. These plants were dirty and smelly, however, and virtually all were closed in the two decades following World War II. A renewed interest in the technology, coincident with reductions in available, convenient landfill capacity and the search for alternative energy sources, occurred in the mid-1970s. In the early and mid-1980s, new MWC capacity was added rapidly, as shown in Table 3-1. The amount of waste combusted increased by a factor of three or four from 1980 to 1986.

TABLE 3-1. ESTIMATED FLOWS OF MUNICIPAL SOLID WASTE TO MUNICIPAL WASTE COMBUSTION PLANTS, 1980 THROUGH 1986

Year	Franklin Associates MWC Waste Flows[a] (10^6 Mg/yr)	Radian[b] MWC Waste Flows (10^6 Mg/yr)
1980	2.45	2.47
1981	2.09	3.45
1982	3.17	4.44
1983	4.54	6.02
1984	5.90	7.60
1985	6.89	9.60
1986	8.71	10.20

[a] Franklin Associates estimates MWC energy recovery waste flows only (Franklin Assoc., 1988, p.18).

[b] In a profile of existing facilities, Radian (1988a) reports estimates for non-heat recovery capacity, heat recovery capacity, and capacity for plants that co-fire MSW with other materials (e.g. wood, tires, sewage sludge). The values reported above include heat recovery capacity for plants processing at least but not less than 50 percent MSW. Average capacity utilization values reported in the *1988-89 Resource Recovery Yearbook* (Gould, 1988) were applied to MWC capacity estimates to calculate waste flows.

Radian Corporation's report, *Municipal Waste Combustion Industry Profile–Facilities Subject to Section 111(d) Guidelines* (Radian, 1988a), lists MWC plants that were operating, under construction, or planned in the mid-1980s. The report identifies 281 plants that might be affected by Guidelines: 161 plants in actual operation at the report's printing date and another 120 that were projected to begin construction before 1990. While quite a number of new plants have begun operating in the past few years, construction plans for many of the projected plants have been deferred or cancelled due to local opposition and/or revisions in community waste management plans. Consequently, the estimated number of plants subject to the Guidelines has been revised downward to reflect these changing market conditions. We estimate that approximately 200 plants (39 projected plus the 161 currently operating plants) will be affected by the Guidelines.

The baseline conditions for MWC plants subject to the NSPSs were derived in part from information compiled by Radian and presented in the NSPSs cost report (EPA, 1989c). Plants identified in this report are those expected to begin construction within the 5-year period following the initial publication of the proposed NSPSs in the *Federal Register*, planned for late 1989. For the purpose of this analysis, MWC plants subject to NSPSs are called "NSPSs plants." The Radian NSPSs cost report projected 138 such NSPSs plants.

For the NSPSs cost report Radian estimates the design capacities and technologies of these NSPSs plants based on a list of plants it compiled from information on plants in the early planning stages. To make these estimates, Radian sometimes used information about plants in advanced planning or early construction stages to assign capacity and technology distribution to plants in early planning stages. Radian projects that approximately 41.3 million Mg per year of capacity will be distributed among 138 plants beginning construction between November 1989 and the end of 1994. This capacity was distributed across MWC technologies as follows: 64 percent mass burn, 27 percent RDF, 7 percent FBC, and 3 percent modular (see Figure 3-3). In constructing the baseline projections for this report, we used Radian's estimates of the distribution of facilities by technology but modified the projections to cover roughly 67 NSPSs plants with a total capacity of 19.3 million Mg per year. This process is described in detail in Chapter 5.

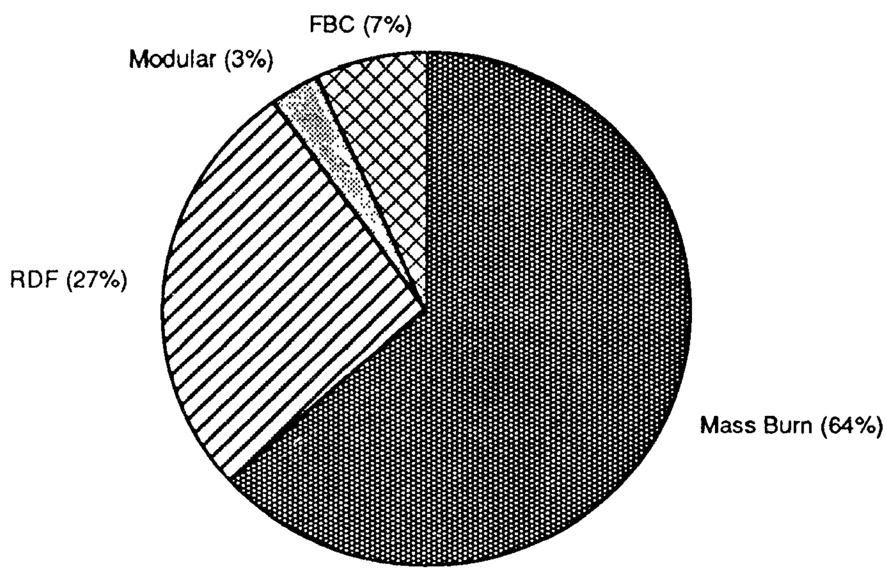


Figure 3-3. Percentages of total capacity of mass burn, RDF, FBC, and modular technologies that will be affected by the NSPSs (Radian, 1988a).

In 1987 the market for MWC construction services sent mixed signals to suppliers of those services. According to a Kidder Peabody report (McCoy, 1988), more capacity was cancelled than was ordered in 1987, with a resulting total scheduled decline in capacity of 10 percent. Public opposition to siting and construction of new plants, combined with the uncertainty regarding proposed legislation, are thought to be the major obstacles facing the vendors of MWC systems. These vendors include project developers, manufacturers, and engineering construction firms. According to the report, 28 companies participate in the combustion industry with no one firm being dominant. Of the 28 firms, Ogden Martin is the 1987 industry leader in terms of capacity, claiming a 20 percent market share. Wheelabrator is in second place with 18 percent, ahead of American Ref-Fuel with 8 percent, Combustion Engineering with 7 percent, and Westinghouse Electric with 5 percent. Generally, the capital services vendors are not the MWC plant owners. Plant ownership has typically been the domain of state or local governments who find it important to retain control over municipal waste disposal services.

Technologies

MWC plants range widely in design capacity from less than 25 to more than 2,000 Mg per day of MSW throughput. As the name suggests, mass burn combustion requires no processing aside from the removal of oversized items and some mixing to produce a more homogeneous fuel (EPA, 1987). Refuse is moved through the plant through the use of grates and/or rams. A traveling grate may carry the MSW through the combustor without agitation, or a rocking (reciprocating) grate may be used to agitate the waste as it moves through the combustor. The rotary design uses a different process to achieve agitation through rotation of the waste. Agitation allows more waste surface to be exposed, increasing efficiency (Robinson, 1986).

Because mass burn plants are built on site, variation in design and capacity are characteristic of this type of MWC. Two typical mass burn design technologies are waterwall and refractory designs. Virtually all waterwall furnaces incorporate energy recovery, but the same is not true for refractory furnaces. The refractory design is an older, less efficient technology and, for this reason, most new mass burn plants are expected to have waterwall boilers.

Modular combustors, like mass burn combustors, require minimal processing of waste. Modular plants consist of one or more prefabricated combustor units and range in capacity from approximately 25 to 500 Mg of MSW throughput per day using either grates or rams to move waste through the combustor. Modular combustors are constructed as "starved air " or "excess air" designs. Both types use similar design components but differ in the amount of oxygen present in the combustion chamber. Excess air combustors incinerate waste with no limits on the amount of oxygen present. Starved air combustors control the amount of oxygen to achieve pyrolysis of MSW.

The modular combustor has primary and secondary combustion chambers. Partial combustion of MSW in the primary chamber is followed by more complete combustion in the secondary chamber assisted by an auxiliary burner and additional air (Robinson, 1986).

The third major category of MWC uses sorted and processed municipal waste referred to as refuse-derived fuel (RDF). The sorting and separating of waste materials is typically accomplished by a system of shredders, magnets, screens, air classifiers, and conveyers, which produce a fuel (waste) that yields a higher heat value, lower ash volume, and more complete combustion than nonprocessed waste. Processing may vary from shredding of refuse to fine separation of waste to produce a fuel suitable for cofiring with a fossil fuel.

The fourth and final category of MWC technology dealt with in this report is Fluidized Bed Combustion (FBC). Several refuse entry points are necessary with FBC to provide even fuel distribution. Combustion chambers use either a waterwall or refractory design for temperature control and energy recovery. Fluidized bed technology allows firing a wide variety of fuels with relative insensitivity to the amount and type of ash in the fuel. By making the waste behave as a liquid or gas, FBC combustion units burn MSW more efficiently than mass burn or RDF units. At present, however, fluidized bed technology is relatively new and still undergoing development.

MWC has two principal products, MSW volume reduction and energy generation, along with the residual products of ash and emissions to the ambient air. The production function for MWC can be expressed by the equation

$$Q_{MWC}, Q_e, Q_a, Q_{env} = f_2(\text{capital services, operating services}, Q_{MSW}) \qquad (3.3)$$

where Q_{MWC} is the volume reduction in MSW, Q_e is the quantity of energy produced, Q_a is the quantity of ash residue generated, and Q_{env} is a measure of the environmental impacts, including air emissions, resulting from incineration. The inputs are capital services (e.g., combustor unit, land, building, air pollution control devices), operating services (e.g., labor services, maintenance services, fuel for cofiring, utility services), and Q_{MSW} (raw MSW for fuel).

Representative plants, called "model plants," are used extensively in this economic impact analysis to represent NSPSs plants nationwide. Radian specifies the technical features of 12 representative model plants in the NSPSs cost report (EPA, 1989c) and assigns the plants identified in the cost report to 1 of these 12 technologies. Table 3-2 provides a list of the model plants and their characteristics including a description of the energy recovery capabilities.

Table 3-3 shows the relationship between inputs and outputs for the model plants used in this analysis. MSW input corresponds to Q_{MSW} in Equation (3.3) and represents design capacity for each model plant. Waste reduction and energy recovery are the principal products of MWC, referred to as output. Estimates for MSW reduction were calculated by subtracting the projected annual volume of residual ash from the projected MSW input per year. Energy recovery figures are based on energy revenue projections divided by a $\$/10^6$ Btu energy value factor derived by Radian (1988c). 10^6 Btu's were then converted to TJ using a conversion factor. The volume of ash and total emission estimates for CDD/CDF, CO, PM, SO_2, HCl, and Pb are included as residual products of MWC.

3.1.2 Landfilling

Two types of landfills are used to manage MSW—sanitary landfills and hazardous waste landfills. Sanitary landfills receive only nonhazardous waste (primarily from household and commercial sources) with the exception of small quantity generator hazardous waste. Sanitary landfilling is defined as a method of waste disposal through a process that includes (Robinson, 1986):

(1) spreading the collected waste into thin layers in the landfill,
(2) compacting the waste into the smallest practical volume, and
(3) covering the waste with soil on a daily basis.

The potential environmental impacts of landfilling (e.g., possible groundwater contamination, air emissions, odor, traffic, dust, and danger of explosion) are becoming widely known. Likewise, health and safety regulations surrounding landfill design, siting, and operation are also becoming increasingly stringent, making landfilling more expensive (Glebs, 1988). As a result of these factors, along with increasing land scarcity, many landfills have closed and communities are facing increasing difficulty developing new landfill sites.

Since 1980 the number of landfills opening each year has continually declined (Temple, Barker, & Sloan, Inc., et al., 1987). Approximately three-quarters of all municipal solid waste landfills currently in operation are expected to close within the next 15 years. Municipalities, especially those in New Jersey, New York, Connecticut, Florida, and California, have been forced to look toward other MSW management options such as recycling and combustion that reduce the quantity of waste to be landfilled.

TABLE 3-2. CHARACTERISTICS OF NSPSs MODEL PLANTS

Model Plant #	Abbreviated Term	Definition of Term	Model Plant Capacity (Mg/day)	Model Plant Size Category[a]	Energy Recovery
1	MB/WW (small)	Mass Burn/Waterwall (small)	180	S	steam
2	MB/WW (mid-size)	Mass Burn/Waterwall (mid-size)	730	L	electric
3	MB/WW (large)	Mass Burn/Waterwall (large)	2,040	L	electric
4	MB/REF	Mass Burn/Refractory Wall	450	S	electric
5	MB/RC	Mass Burn/Rotary Combustor	950	L	electric
6	RDF	Refuse Derived Fuel	1,810	L	electric
7	RDF/CF	Refuse Derived Fuel/Co-fired	1,810	L	electric
8	MOD/EA	Modular/Excess Air	220	S	electric
9	MOD/SA (small)	Modular/Starved Air (small)	45	S	none
10	MOD/SA (mid-size)	Modular/Starved Air (mid-size)	90	S	electric
11	FBC/CB	Fluidized Bed Combustion (Circulating Bed)	820	L	electric
12	FBC/BB	Fluidized Bed Combustion (Bubbling Bed)	820	L	electric

[a] Model Plants with design capacity less than or equal to 225 Mg/day are classified as small and plants with capacity greater than 225 Mg/day are classified as large. Specified control technologies are assigned to model plants under various regulatory alternatives according to this size classification.

TABLE 3-3. PRODUCTION CHARACTERISTICS OF NSPSs MODEL PLANTS[a]

			MSW Input		Outputs		Residuals	
Model Plant #	Combustor Type	Annual Hours Operation[b]	(Mg/day)[c]	(Mg/yr)[b]	MSW Reduction[e] (Mg/yr)	Energy Recovery[f] (TJ/yr)	Ash[g] (Mg/yr)	Selected Air Emissions[h] (Mg/yr)
Mass Burn								
1	MB/WW (small)	5,000[d]	180	37,800	27,700	0.404	12,100	255
4	MB/REF	7,420	450	140,000	95,500	1.18	44,700	980
2	MB/WW (mid-size)	7,420	730	224,000	153,000	2.41	71,600	1,450
5	MB/RC	7,420	950	294,000	200,000	3.25	94,000	1,970
3	MB/WW (large)	7,420	2,040	631,000	430,000	6.75	201,000	4,060
Refuse-Derived Fuel								
7	RDF/CF	3,620[d]	1,810	274,000	196,000	7.83	77,900	2,860
6	RDF	7,250	1,810	548,000	467,000	7.06	80,900	5,060
Modular								
9	MOD/SA (small)	5,000[d]	45	9,450	6,610	0	2,840	66
10	MOD/SA (mid-size)	7,160	90	27,000	18,900	0.290	8,120	183
8	MOD/EA	7,160	220	64,900	44,200	0.695	20,700	457
Fluidized Bed Combustion								
11	FBC/BB	7,270	820	247,000	229,000	3.19	18,700	1,590
12	FBC/CB	7,270	820	247,000	229,000	3.19	18,700	1,630

[a] Values are rounded to three significant digits. Differences across columns due to rounding. Model plants represent average characteristics for projected MWC facilities.

[b] Calculated using average capacity utilization reported in the *1988-89 Resource Recovery Yearbook* (Gould, 1988). Allowance is made for increased downtime for model plants 1 and 9; and allowance is also made for model plant 7 which co-fires 50 percent wood.

[c] Based on a 24-hour operating day.

[d] Reflects special conditions resulting from increased estimated downtime for smaller plants and co-firing other materials with MSW (e.g. wood chips, tires, sludge, etc.).

[e] Calculated by subtracting ash residual from MSW input (Mg/yr).

[f] Based on energy revenue credits and $\$/10^6$ Btu reported in a memorandum from Radian (1988c).

[g] Ash values include some residual quench water.

[h] Represents sum of 6 types of emissions: polychlorinated dibenzo-*p*-dioxins and dibenzofurans (CDD/CDF), carbon monoxide (CO), particulate matter (PM), sulfur dioxide (SO_2), hydrogen chloride (HCl), and lead (Pb).

Landfill sites may be constructed according to various design technologies (Robinson, 1986). The trench method involves excavating soil at a slight angle to facilitate drainage. Facilities using this type of landfill technology must consider soil depth and groundwater conditions. MSW is then spread in the trench, compacted, and covered with material taken from the spoil of excavation with the excess material used for berms or area landfills. The trench method:

- makes cover material readily available,
- exposes a minimum-size working face,
- gives optimum drainage during filling operations, and
- is easily adapted to wide variation in size of operation.

In the area method of landfilling, waste is spread on the ground with no prior excavation. After the waste is compacted, it is covered with imported soil. This method is generally used in locations with land depressions or gently sloping land. The area method:

- accommodates very large operations (large working face), and
- is acceptable where no below ground excavation is feasible.

Combinations of the trench and area methods allow for the greatest flexibility in adapting site construction to the particular needs of a community. The progressive slope or ramp method is one variation in which a small amount of soil is excavated directly adjacent to the working face and spread over one day's waste. The depression is then filled with a portion of the next day's waste, which is covered with soil from another adjacent excavation. Using this method eliminates the need to import cover material and allows a portion of the discarded waste to be deposited below the original surface.

The state-of-the-art landfill may include clay or synthetic liners, leachate collection and monitoring, gas collection and monitoring, surface water controls, and groundwater monitoring. However, the majority of landfills have little environmental protection equipment in place. Ninety-five percent have no leachate collection, and 85 percent do not have a liner. Only 25 percent monitor groundwater, and only 12 percent practice surface water monitoring. Landfill gas is monitored even less, with 5 percent of the sites incorporating methane monitoring (Glebs, 1988).

Subtitle D regulations under the Resource Conservation and Recovery Act of 1976 (RCRA) proposed in the August 30, 1988, *Federal Register* may significantly increase the cost of developing landfill sites. The proposed rule would require existing landfills to incorporate closure and post-closure care including groundwater, surface water, and gas monitoring and to provide final cover integrity. Additional regulations for new landfills require that sites be developed with a liner as well as other detection and monitoring equipment necessary to ensure the integrity of groundwater and surface water within concentration limits set by the EPA.

As the cost of landfilling rises, the industry may be able to offset some of the costs through energy recovery. Methane gas is formed as solid waste decomposes. The concentration and quality of methane vary according to the extent of MSW decomposition, quality of the MSW being landfilled, climatic conditions, and parameters of the landfill. Typically, the gas collection system consists of vertical wells and horizontal collection headers distributed over the surface of the landfill site (Jansen, 1986). After the gas is collected it is either upgraded for delivery to utility companies, used as boiler fuel, or converted into electricity by an internal combustion engine (Robinson, 1986). Energy recovery through gas collection is generally limited to large, established landfills since methane formation may take a period of several years and require a relatively sizable area of land for mining operations.

The production function for landfilling MSW can be expressed by

$$Q_L, Q_e, Q_{env} = f_3(\text{capital services, land, operating services}, Q_{MSW}) \tag{3.4}$$

where Q_L is the quantity of MSW landfilled per year, Q_e is the quantity of energy produced per year from the combustion of methane and other combustible gases generated from decaying waste, and Q_{env} is a measure of the environmental impacts per year resulting from landfilling. The inputs are capital services (e.g., bulldozers, scales, buildings, air pollution control devices), land, operating services (e.g., labor services, maintenance services, utility services), and Q_{MSW} (municipal solid waste).

The amount of land needed for sanitary landfills depends on the depth of the site, the degree of waste compaction, and the desired closing height of the landfill. However, a rule of thumb is that one hectare is required annually for every 12,000 people, or, based on average waste generation rates, for every 6,200 Mg of MSW generated.

According to the Solid Waste Landfill Survey conducted by the EPA (1988b), 80 percent of sanitary landfills are owned by local governments. An additional 5 percent are owned by state and federal governments with the remaining 15 percent privately owned. A correlation between type of ownership and size of the landfill has been observed, with publicly owned landfills more likely to be small and privately owned landfills large. Half of the landfills in operation (the smallest ones) receive less than 2 percent of the waste while 2.6 percent of landfills (the largest ones) receive 40 percent of the waste (RTI, 1988b).

Hazardous waste landfilling is the placement of hazardous waste in or on land, often in cells that are subsequently covered with clay, asphalt, or concrete. Hazardous waste landfills are made leak resistant by the use of combination clay and synthetic liners. Leachate detection and groundwater monitoring systems alert operators to the existence of a leak (Environmental Law Institute, 1983). The treatment, storage, and disposal of hazardous wastes are regulated under RCRA Subtitle C, requiring operators of these landfills to keep a careful account of the types of wastes disposed and ensure the protection of groundwater and surface water within established environmental performance standards.

Because MWC fly ash has a high heavy metals content, there have been proposals to treat it as a hazardous waste. The Science Advisory Board, a body of independent scientists, is currently reviewing an overall approach to the handling, transportation, and disposal of ash from municipal incineration. Rep. Thomas Luken (D-Ohio) introduced an incinerator ash bill (H.R. 2162) on May 1, 1989, which would mandate EPA regulation of solid waste incineration and disposal of ash. Under the provisions of this bill, incinerator ash that fails to meet minimum technical standards would be restricted to a RCRA Subtitle D monofill or codisposal facility (*Hazardous Waste News,* May 8,1989).

The production function for hazardous waste landfilling of fly ash can be expressed by

$$Q_{LA}, Q_{env} = f_4(\text{capital services, land, operating services}, Q_A) \qquad (3.5)$$

where Q_{LA} is the quantity of ash landfilled per year, Q_{env} is a measure of the environmental impacts per year resulting from landfilling, and the inputs are capital services (e.g., bulldozers, scales, building, air pollution control devices, leachate containment systems), land, operating services (e.g., labor services, maintenance services, utility services), and Q_A (ash).

3.1.3 Collection and Transportation

Collection and transportation of MSW are common components of every MSW management system. MSW is collected from generators and transported to the treatment plant or directly to the landfill. Where recycling or combustion are performed, the residue is subsequently transported to the ultimate disposal site. Transfer stations are widely accepted in large metropolitan areas as a means of reducing transportation costs, especially when landfill sites are remote. A transfer station is a waste holding place located between waste collection points and disposal plants. When a transfer station is used, transportation is also needed from the transfer station to the primary management plant. Other advantages of transfer stations include (Robinson, 1986):

- better haul roads for collection vehicles,
- greater traffic control,
- fewer trucks on the sanitary landfill haul route, and
- improved landfill operating efficiency.

The production function for transporting MSW can be expressed by

$$Q_{MSW} = f_1(\text{capital services, operating services}) \tag{3.6}$$

where Q_{MSW} is the quantity per kilometer of MSW transported per year and the inputs are capital services (e.g., trucks, buildings, land) and operating services (e.g., labor services, repair services, fuel, management services).

3.1.4 Recycling

Materials may be recovered from MSW and recycled using one or both of two methods—generator sorting (sometimes called curbside recycling in a residential context) and centralized recycling. In the U.S., most materials are first recovered through generator sorting, in which generators manually separate materials for reuse or recycling from waste for disposal. For example, in some communities households are required to separate paper, glass, and metals from their waste for curbside collection. Centralized recycling plants separate salable materials from mixed waste after collection, often as part of transfer station operation.

Centralized recycling is often practiced in conjunction with combustion of RDF. Operators of MWC plants that burn RDF have an interest in promoting the recycling of bottles and cans to reduce the amount of these materials appearing in the fuel (waste). The sorting and separating required for plants using RDF couples naturally with recycling programs. Combustion Engineering agreed in 1987 to build a combination materials recovery plant and combustion plant for a community in New York (Salimando, 1988). Increased quality of waste, reduced need for landfill services, and reduced amount of ferrous metal in ash residue are some of the benefits associated with arrangements of this type.

Recycling increases landfill life since processed materials tend to require less capacity than nonprocessed waste. Enhancing the efficiency of existing landfill sites reduces the need for new site development. However, institutional problems associated with source separation include reinvestment problems and labor problems. Single compartment collection vehicles are not efficient for curbside collection of separated materials. In addition, the retraining of a labor force that has traditionally viewed discarded materials as "waste" further compounds the difficulties associated with recycling. As a result, recycling programs are often not regarded as viable options for decision makers who are risk-averse.

3.2 PRODUCTION COSTS

The production function of Equation 3.2 describes the relationship between inputs and the maximum output rate. Correspondingly, at a given output rate, Q, the minimum input requirements can be identified as

$$X_1,\ldots\ldots,X_m = g(\bar{Q}). \qquad (3.7)$$

The cost of production at $\bar{Q}$ is the sum of the amount of X employed times its price. For each output, $\bar{Q}$, the minimum cost way of producing that output is defined by the cost function

$$C_{min} = f(X_1,\ldots\ldots,X_m; \bar{Q}). \qquad (3.8)$$

This cost-minimizing set of inputs for a given level of Q can be estimated for each of the waste management processes identified in Section 3.1. The following sections of this chapter describe production cost estimates developed for three of the four waste management activities discussed above—combustion, landfilling, and collection and transportation. Costs for recycling are not developed because this analysis treats changes in the waste stream associated with recycling or source reduction as exogenous. That is, reductions in the volume or composition of waste to be transported and disposed by landfills and combustors due to generator sorting and recycling can be varied but are taken as given in the analysis.

Given input prices, the C variable can be expressed as three cash flows: capital costs, operating costs, and closure costs or salvage value. In general, the net present cost of producing a given output of collection and transportation, landfill, or combustion service can be expressed by the cash flow expression

$$\begin{pmatrix}\text{Net}\\\text{Present}\\\text{Cost}\end{pmatrix} = \begin{pmatrix}\textbf{A}\\\text{Present value of}\\\text{Capital Costs}\end{pmatrix} + \begin{pmatrix}\textbf{B}\\\text{Present value of}\\\text{Operating Costs}\end{pmatrix} - \begin{pmatrix}\textbf{C}\\\text{Present Value of}\\\text{Salvage Recovery}\end{pmatrix}.$$

In the first portion of the equation, (A), capital costs may be a stream of lumpy investments or a one-time investment. Operating costs (B) for each period are calculated net of energy recovery revenue, and salvage value (C) of plant and equipment, if any, is also accounted for. Actual calculations involve some differences for private and public ownership due to different cost-of-capital figures and tax obligations for those forms of ownership.

The net present cost equations for the two types of ownership are as follows:

Private Financial Cash Flow

$$NPC_p = \overbrace{\left[\sum_{t=1}^{T} K_{t-1}\,(1+r_p)^{-(t-1)}\right]}^{\textbf{A}} + \overbrace{\left[\sum_{t=1}^{T} \left\{(C_t - R_t)(1-x_e) - D_t x_e (1+r_i)^{-t}\right\}(1+r_p)^{-t}\right]}^{\textbf{B}}$$

$$- \overbrace{\left[S(1+r_p)^{-T}\right]}^{\textbf{C}} \qquad (3.9)$$

Public Financial Cash Flow (municipalities)

$$NPC_m = \overbrace{\left[\sum_{t=1}^{T} K_{t-1}\,(1+r_m)^{-(t-1)}\right]}^{\textbf{A}} + \overbrace{\left[\sum_{t=1}^{T} (C_t - R_t)(1+r_m)^{-t}\right]}^{\textbf{B}} - \overbrace{\left[S(1+r_m)^{-T}\right]}^{\textbf{C}} \qquad (3.10)$$

where

K_{t-1} = Capital cost at time t-1 (the beginning of period t), including land, equipment, and structures.

t = Time period with initial construction at t = 0.

C_t = Operating costs, including labor, materials and supplies, interest on debt, management and administration, working capital, property taxes, and insurance. These occur at the end of each period t.

S = Salvage value of equipment and land net of decommissioning costs.

T = Operating life of the plant with T designating the final point in time for purposes of the analysis.

r_p, r_m = Private and public real rates of discount ($r_p = .08$; $r_m = .04$). See Appendix A for a discussion of estimation of these parameters.

r_i = Expected real inflation rate ($r_i = .04$).

D_t = Depreciation accrued in the t^{th} period. It is calculated as a straight line over th life of the plant.

x_e = Effective tax rate equal to $x_s + (1 - x_s)x_f$, where x_s and x_f are the state and federal average tax rates ($x_s = .07$; $x_f = .35$).

R_t = Credits from associated sale of electricity and steam.

Time periods in the analysis are denoted by t. Capital expenditures are considered incurred at the beginning of a period. As a consequence, the capital expenditures of the first period are denoted K_{t-1}. Cash flows, operating expenditures, and revenues are considered to occur at the end of a period and are subscripted accordingly. For example, the first period costs are C_1 and the fifth-period revenues are R_5.

There are T periods in the analysis, the final point in time designated by T. Salvage value revenues (S) are shown as occurring at the end of operation, and are thus discounted by the factor $(1+r_p)^{-T}$.

Since these expressions are for net present value of "costs," the cost components have positive signs and the revenue components—sales, tax savings, and salvage value income—have negative signs.

All flows are expressed in real terms or adjusted to be in real terms (e.g., the depreciation tax saving). The following assumptions were used in formulating and implementing the equations:

1. The economic life and the engineering life of the plant are both T.
2. Depreciation for tax purposes is "straight line."
3. r_p and r_m are symmetric with respect to borrowing or investing. There are no differences in risk or transaction costs between these opportunities.
4. Costs in excess of revenues can be charged against revenues from other activities in a period to obtain the tax deductibility of current period costs.
5. Marginal tax rates equal average tax rates.
6. Property taxes are included in operating costs.

A major interest in calculating cash flows is to find the increase in tipping fees that would be needed to offset the after-tax cost. For private firms, the net present value (NPV_p) of offsetting revenue is shown in Equation (3.11).

$$NPVp = \frac{NPC_p}{1-x_e} \qquad (3.11)$$

The denominator $(1-x_e)$ allows for taxes that the private firm must pay on net revenues. The "cost," in this context, is the estimated present value of offsetting revenue required by the plant's owners if the full cost of the regulation to the plant is passed through to users in the form of tipping fee increases. This adjustment is not needed for calculating NPV_m because public entities don't pay taxes on net revenues [$NPV_m = NPC_m$].

Using these NPV equations to derive present value costs allows for comparison among various management alternatives facing a single entity. In some situations the equations may not be appropriate for comparing costs between two entities if those entities are different from each other in financial structure. For example, two private firms, each with unique reinvestment options and tax liabilities, require two different equations, each tailored to its firm's financial situation. Comparisons between public and private firm cost of control made with these equations are presented in Chapter 6, Table 6-2. Because public and private firms are inherently different in financial and, perhaps, cost structure, the comparisons must be interpreted with care.

In Chapter 6 the NPV values are used to calculate annualized equivalents for the cost of control for different model plants as well as for different plant ownership. The latter are then divided by annual throughputs to obtain annualized $/Mg figures that are convenient for comparing regulatory alternatives. Again, the same caution applies when comparing $/Mg costs. The annualized $/Mg cost for a private firm or public entity is an approximation of the amount it would have to charge in additional tipping fees in order to pass all costs along to MSW collectors or generators, but there can be quite a bit of variation depending on the circumstances of individual firms and public entities.

3.2.1 Combustion

Analysis of MWC costs using the cash flow model presented above provides a framework for comparing costs as among plants and estimating cost impacts of regulatory alternatives for a given plant. For the purposes of depreciation, the life of new plants is assumed to be 30 years. Control equipment is assumed to have two consecutive 15-year life cycles. Salvage value, net of decommissioning costs, is assumed to be zero in our calculations.

Table 3-4 provides estimated costs for NSPSs model plants. As noted above, these model plants are used in this report as representative of certain types of MWC plants based on MWC technology and capacity. The NSPSs model plants and their costs are described in detail in Radian's cost report (EPA, 1989c). The dollar measures used throughout the report for model plants are December 1987 dollars.

TABLE 3-4. PRODUCTION-COST RELATIONSHIPS OF NSPSs MODEL PLANTS ($1987)[a]

Model Plant #	MSW Input	Costs: Capital Costs	Costs: Operating Costs		Revenue from Energy Recovery		Annualized Capital Plus Operating Costs (Net of Energy Recovery Revenue)[d]: Privately Owned Facilities[e]		Publicly Owned Facilities[f]	
	(Mg/yr)[c]	($10³)	($10³/yr)	($/Mg)	($10³/yr)	($/Mg)	($10³/yr)	($/Mg)	($10³/yr)	($/Mg)
Mass Burn										
1	37,800[d]	19,700	2,680	71.00	1,040	27.40	4,260	113.00	2,850	75.40
4	140,000	40,400	6,750	48.10	3,020	21.50	9,360	61.90	6,170	44.00
2	224,000	53,200	7,610	33.90	6,160	27.50	8,580	35.50	4,640	20.70
5	294,000	73,300	10,200	34.60	8,310	28.20	11,700	36.80	6,260	21.30
3	631,000	117,000	16,200	25.70	17,300	27.40	14,300	21.00	5,930	9.40
Refuse-Derived Fuel										
7	274,000	152,000	15,900	29.00	24,200	44.20	10,700	17.75	4,850	17.70
6	584,000	143,000	15,300	27.90	21,800	39.90	11,600	19.11	1,961	3.58
Modular										
9	9,450[d]	1,270	439	46.50	0	0	605	64.00	512	54.20
10	27,000	5,880	1,050	38.60	582	21.50	1,310	43.40	845	31.20
8	64,900	14,500	2,490	38.40	1,400	21.50	3,140	43.30	1,980	30.40
FBC										
11	247,000	73,900	8,720	35.20	9,860	39.90	8,460	31.10	3,250	13.20
12	247,000	73,900	8,720	35.20	9,860	39.90	8,460	31.10	3,250	13.20

[a] Cost and input numbers are rounded to three significant digits. Model plants represent average characteristics for new MWC facilities. Differences across columns due to rounding.
[b] Based on a 24-hour operating day
[c] Calculated using average capacity utilization reported in the *1988-89 Resource Recovery Yearbook* (Gould, 1988). Allowance is made for increased downtime for model plants 1 and 9; and allowance is also made for model plant 7 which co-fires 50 percent wood.
[d] Differences in annualized operating costs for privately and publicly owned facilities are due to differences in the cash flow models for these firms as well as differences in cash flow model parameters, especially the discount rate. See text for a discussion of these differences.
[e] Private discount rate = 8 percent
[f] Public discount rate = 4 percent.

Operating costs for NSPSs plants in Table 3-4 include ongoing costs related to operation and maintenance of the combustor unit, ash disposal, and auxiliary fuel use. Not included in the baseline cost figures are any additional costs associated with the proposed NSPSs. Annualized $/Mg unit costs of NSPSs plants decrease as MSW input increases, indicating economies of scale, over the ranges for each technology used in this analysis.

3.2.2 Landfilling

Landfill capital costs have two components—capital equipment and land. By combining these two costs and treating land resale value as a component of salvage value, the total cost of a MSW landfill can be represented by the net present cost equation used for combustors. As with MWC plants, landfill costs are expressed in both private and public financial forms (see Table 3-5).

EPA has implemented revisions to Subtitle D criteria for MSW sanitary landfills. These regulations impose standards that will increase landfill costs because they require landfills to provide closure and post-closure care including groundwater, surface water, and gas monitoring systems and final cover integrity. Table 3-5 also presents these Subtitle D control costs for sanitary landfills. Unit costs decrease with increased throughput, indicating the existence of economies of scale in MSW landfilling.

The data presented in Tables 3-5, 3-6, and 3-7 have not been estimated using the cash flow model and parameters discussed previously and applied to combustor model plants. To provide the reader with a general idea of the costs of these MSW management activities, related but not strictly comparable data are presented in these tables.

Hazardous waste landfills are more expensive than sanitary landfills. This is due primarily to the systems designed to prevent and detect groundwater contamination. Closure of hazardous waste landfills is also highly regulated and much more expensive than closure of sanitary landfills. The capital, land, and operating costs for hazardous waste landfilling are presented in Table 3-6. The unit costs decrease with increased throughput, indicating the presence of economies of scale.

3.2.3 Collection and Transportation

The cost of transporting MSW increases with the distance the waste is hauled and with the traffic congestion along the haul route (Robinson, 1986). Transportation cost estimates are presented in Table 3-7 for alternative distances and traffic congestion situations. Costs increase with distance at a constant rate. Average costs decrease (i.e., cost/Mg/km) due to the presence of fixed costs.

TABLE 3-5. PRODUCTION-COST RELATIONSHIPS OF LANDFILLS [a,b]

MSW Input (Mg/day)	MSW Input (Mg/yr)	Capital Costs ($10^3)	Operating Costs ($10^3/yr)	Baseline Annualized Cost per Mg MSW: Public ($/Mg)	Baseline Annualized Cost per Mg MSW: Private ($/Mg)	Subtitle D Annualized Cost per Mg MSW: Public ($/Mg)	Subtitle D Annualized Cost per Mg MSW: Private ($/Mg)	Total Annualized Cost per Mg MSW: Public ($/Mg)	Total Annualized Cost per Mg MSW: Private ($/Mg)
10	2,360	1,700	44,400	71.90	92.20	18.50	23.80	90.40	116.00
25	5,900	3,020	35,800	43.80	58.20	12.90	17.20	56.70	75.40
70	17,700	6,200	91,400	31.00	40.90	7.89	10.40	38.80	51.30
160	41,300	8,050	95,500	16.70	22.20	5.98	7.96	22.70	30.15
340	88,400	11,700	87,600	10.80	14.50	4.33	5.84	15.10	20.30
680	177,000	17,000	156,000	7.97	10.70	2.85	3.83	10.80	14.50
1,360	354,000	34,500	229,000	7.83	10.60	2.82	3.82	10.70	14.40

[a] Cost and input numbers are rounded to three significant digits. Details may not add to totals due to rounding.

[b] Differences in annualized operating costs for privately and publicly owned facilities are due to differences in the discount rate. Public discount rate: 4%; Private discount rate: 8%.

Source: Temple, Barker, and Sloan, Inc., ICF, Inc., and Pope-Reid Associates. 1987. *Draft Regulatory Impact Analysis of Proposed Revisions to Subtitle D Criteria for Municipal Solid Waste Landfills*. Prepared for the U.S. Environmental Protection Agency, Office of Solid Waste.

TABLE 3-6. COSTS OF HAZARDOUS WASTE LANDFILLING[a]

	Small (450 Mg/yr) ($/Mg)	Large (55,000 Mg/yr) ($/Mg)
Capital	186.80	8.48
Land	21.94	1.08
Operating	383.20	45.65
TOTAL	591.94	55.21

[a] Values converted to $1987 dollars using the GNP implicit price deflator.

Source: Research Triangle Institute. 1986. *A Profile of the Market for Hazardous Waste Management Services*, pp.D-67 to D-68. Draft Report prepared for the U.S. Environmental Protection Agency.

TABLE 3-7. COSTS OF COLLECTING AND TRANSPORTING MUNICIPAL SOLID WASTE[a]

	Traffic Congestion (%rural/%suburban/%urban)			
	100/0/0 ($/Mg)	50/25/25 ($/Mg)	25/50/25 ($/Mg)	25/25/50 ($/Mg)
10 kilometers	2.95	3.11	3.15	3.22
25 kilometers	4.90	5.26	5.35	5.50
50 kilometers	7.84	8.48	8.62	8.92
100 kilometers	13.71	14.92	15.19	15.75

[a] Costs refer to one-way trips. Values converted to $1987 using GNP implicit price deflator.

Source: Robinson, William D., ed. 1986. *The Solid Waste Handbook: A Practical Guide*. Wiley-Interscience.

CHAPTER 4
MUNICIPAL SOLID WASTE MANAGEMENT

The discussion of demand and supply conditions in Chapters 2 and 3 focuses on the historic activity levels and technical relationships associated with municipal waste combustion and, more generally, solid waste management. As that discussion shows, analysis of the municipal solid waste (MSW) management system is complicated by the many process options available. In this chapter we examine another complicating feature of the municipal waste management system: the role that public entities play as both shapers of, and participants in, that system. In particular, we examine their role in two interrelated exchanges: the exchange between waste generator and waste collector and that between waste collector and waste disposer. We then conclude with a discussion of solid waste management decision making by public and private entities.

4.1 PUBLIC INVOLVEMENT IN THE MSW SYSTEM

Public entities—local, state, and federal—play a large role in regulating and operating MSW management systems. Their influence, however, is not unlimited. Material, engineering, geographic, cost, and other technical and economic conditions certainly apply to both public and private entities.

In addition, all MSW management systems ultimately involve private decision makers and associated markets. Households and private firms generate MSW, collect and transport MSW, build and operate MSW disposal systems, provide financing, and provide markets for recycled material. In some settings these private activities compete with public operations; in others, they provide factors of production and demand for outputs from public operations. Whatever the case, these technical and market relationships are important factors in conditioning the influence of public entities on MSW management generally and the economic impact of changes in the cost of municipal waste combustion in particular.

Having noted this, however, we now examine in more detail the nature and extent of public involvement in MSW management and the way this involvement shapes the economic impact of NSPSs on municipal waste combustors (MWCs).

4.1.1 Local Government

Local communities, especially in more urbanized areas, often take the lead in organizing MSW management and, in many cases, providing collection and disposal services. A wide variety of reasons explain this involvement: concern for the public health threat of uncollected or improperly disposed MSW, natural economies of scale in organizing and performing MSW collection and disposal, and a concern for the negative externalities sometimes associated with private collection and disposal (e.g., litter, noise, smells, traffic) that, while not necessarily unhealthy, may diminish public welfare.

How extensive is the local government role? Stevens (1978) identifies four market structures for MSW collection:

- Public monopoly—public agency collects all MSW.
- Private monopoly—private firm(s) collect(s) all MSW in a specific area under a franchise agreement and is (are) reimbursed by a public entity.
- Competitive—public agency and private firm(s) both collect MSW.
- Self service—generators haul their MSW to disposal sites.

Savas and Niemczewski (1976) estimate that over 80 percent of residential refuse is collected under the first three market structures. Goddard (1975) estimated the share of public and private collection from households, commercial, and industrial customers. These data, presented in Table 4-1, show that public collection is most common for household refuse, accounting for about 50 percent of collection service. Furthermore, some significant fraction of private service was probably provided by contractors selected by public entities. In that case, the public entity played a role in selecting the private collection firm, specifying the terms and conditions of collection, and paying the private collector for the service.

TABLE 4-1. TYPES OF SOLID WASTE COLLECTION (PERCENT OF GENERATORS SERVED)

	Collection Agency		
Generator	**Public**	**Private**	**Self**
Household	50	32 (50)	12
Commercial	25	62 (91)	13
Industrial	13	57 (94)	30

Sources: U.S. DHEW. 1968. *The National Solid Wastes Survey: An Interim Report.* Cincinnati, Ohio. U.S. Public Health Service. (Cited in Goddard, 1975.) Estimates in parentheses are from the National Solid Wastes Management Association. 1972. *The Private Sector in Solid Waste Management.* Washington, DC. (Cited in Goddard, 1975.)

Local public policy with respect to financing waste collection is important to determining the economic impact of the NSPSs. First, the price for waste collection paid by generators may affect their waste generation—higher prices elicit lower generation and vice versa. Second, where waste generators don't directly pay for collection costs, then others, usually taxpayers, do. Goddard (1975) presents two tables on financing solid waste collection, which are reproduced here as Tables 4-2 and 4-3. We observe that half of the municipalities use *only* general taxes to pay for collection and that larger cities are more likely to pay the cost of collection out of tax revenues. Since these data were gathered, however, there has been a trend toward greater emphasis on user fees as a source of local government revenue. This trend includes MSW collection. Even so, user fees assigned to individual MSW generators often do not vary with the amount of MSW produced. Generators are usually charged a flat fee per container or up to a given number of containers. This type of pricing structure diminishes the impact of any changes in the price of collection on the amount of waste generated. Furthermore, to the extent that control costs for compliance with NSPSs are financed out of general revenues rather than through charges, called tipping fees, paid by those unloading at the combustor, the additional costs will not even have a chance to influence waste generation in those jurisdictions with a system of user fees for collection.

TABLE 4-2. METHODS OF FINANCING SOLID WASTE COLLECTION BY COLLECTION AGENCY, 1964[a] (NUMBER OF CITIES)

	Collection Agency						
Method of Finance	**M**	**M,C**	**M,P**	**M,C,P**	**C**	**C,P**	**Percent**
General tax[b]	209	25	81	20	68	26	50
Service charge	149	24	37	4	74	11	35
Tax and service charge	69	10	29	4	8	4	14
Other	2	1	0	1	1	0	1

Key: M=Municipal
C=Contract
P=Private

[a] Sample size is 957.
[b] Such as property, income, or sales tax.
Source: Goddard, Haynes C. 1975. *Managing Solid Waste.* New York: Praeger Publishers. p. 41.

TABLE 4-3. METHODS OF FINANCING SOLID WASTE COLLECTION BY CITY SIZE, 1964 (PERCENT)

Method of Finance	Population						
	5,000 to 9,000	10,000 to 24,999	25,000 to 49,999	50,000 to 99,999	100,000 to 999,999	1,000,000 and Over	TOTAL
General Tax	47.2	46.0	51.5	58.0	59.6	66.6	50.1
Service Charge	39.0	38.0	32.7	28.0	27.0	0.0	34.9
Tax and Service Charge	13.4	16.6	14.2	12.9	13.5	33.4	14.4
Other	0.6	0.0	1.6	1.1	0.0	0.0	0.6
Number of Cities	180	307	190	93	74	6	850

Source: Goddard, Haynes C. 1975. *Managing Solid Waste*. New York: Praeger Publishers. p. 41.

Waste disposal facilities, especially landfills, are more likely to be owned or operated by government entities than are collection services.[1] The EPA survey of 149 existing MWC systems (1988a) requested information on owners and operators. The 106 responses received and processed to date are tabulated in Table 4-4. The 25 respondents that provided distinct ownership information reported that 78 percent were publicly owned and 64 percent were publicly owned and operated.

TABLE 4-4. OWNERSHIP OF MUNICIPAL WASTE COMBUSTION PLANTS, BY SIZE

	Waste Received (10^3 Mg per year)						
Ownership	<10	10-30	30-50	50-100	100-250	>250	ALL
Public	7	12	8	8	14	10	59
Private	5	5	1	4	0	1	16
Unknown[a]							31
TOTAL							106

[a]Ownership data not currently available.
Source: Research Triangle Institute. 1988. Memo to EPA on responses to Section 114 survey letters.

A similar table on public and private ownership and operation of landfills was complied from an EPA survey of nearly 20 percent of the operating landfill units (EPA, 1988b). Table 4-5 shows that over 70 percent of the landfills are publicly owned. In general, local entities feel a strong responsibility to ensure that MSW generated and collected in their jurisdiction has a proper place to go. They often believe that owning or operating the disposal facility provides them with the necessary control. For instance, while several private firms recently submitted bids to operate the Wake County, NC, landfills, the City of Raleigh substantially underbid its competition to win the contract. The difference in the bids was not entirely a reflection of higher operating productivity on the part of the City; it appears to have been all or in large part a reflection of the City of Raleigh's desire to ensure that its residents have an accessible and appropriately run disposal site for MSW (Tucker, 1988).

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[1]In waste disposal facilities in particular it is not uncommon for the operator of the facility to be different from the owner.

TABLE 4-5. OWNERSHIP OF LANDFILLS, BY SIZE

Ownership	Waste Received (10^3 Mg per year)						
	<0.9	0.9-9	9-45	45-90	90-180	>180	TOTAL
Public	1,596	1,548	1,098	362	225	222	5,051
Private	198	178	147	112	24	143	802
Unknown	15	8	28	34	11	85	181
TOTAL	1,809	1,734	1,273	508	260	450	6,034

Source: U.S. Environmental Protection Agency. 1988. *National Survey of Solid Waste (Municipal) Landfill Facilities*. Final report prepared by Westat, Inc., under contract 68-01-7359.

An interesting finding of both surveys is that a sizable fraction of combustors and landfills are owned or operated by a regional entity. For example, the combustor in Duluth, MN, is owned and operated by a special service district created by the state legislature. This district has responsibility for wastewater and MSW treatment of some half dozen municipalities in the Duluth area. There is a trend—due to economies of scale in certain MSW management operations and state government policy and legislation—toward forming sanitation authorities that encompass multiple local government jurisdictions.

Financing of disposal systems owned by a public entity, like financing of MSW collection, can be based on user fees, general tax revenues, or some combination of the two. About 25 percent of landfills charge a price or tipping fee for MSW disposal services (Pettit, 1988). In 1988, the average tipping fee at landfills that have this charge was $29.70 per Mg; the charge at resource recovery (combustion) facilities was $43.96 per Mg (Pettit, 1989). Since collectors would be indifferent between a landfill or a resource recovery facility, the service provided must be different at the two types of facilities. The most likely explanation for the fee difference is that it reflects regional differences. When fees are charged they do not usually cover all the costs of disposal; general tax revenues make up the difference between revenues and costs. When fees are not charged, access to disposal facilities is typically restricted to service area collection crews and, sometimes, residents.

State and federal grants have also been used to finance some of the cost of publicly owned disposal facilities, particularly when experimental disposal systems are involved. Tables 4-6 and

4-7 show tabulations of responses related to plant financing as reported to EPA in its survey of existing facilities. These tables present the reported extent to which MWC owners' revenues come from sources other than the sale of waste management services, energy, or recycled materials. Such sources include subsidies and grants from state and federal government agencies.

TABLE 4-6. TOTAL OPERATING SUBSIDIES AS A SHARE OF TOTAL REVENUES (MUNICIPAL WASTE COMBUSTION PLANTS ONLY)

Percentage of Total Revenues	Frequency	Relative Frequency
0	47	.746
1-20	2	.032
20-40	4	.063
40-60	3	.048
60-80	5	.079
80-100	2	.032
Total	63	1.000

Source: Research Triangle Institute. 1988. Memo to EPA on responses to Section 114 survey letters.

TABLE 4-7. GRANTS AS A SHARE OF TOTAL CAPITAL COSTS (MUNICIPAL WASTE COMBUSTION PLANTS ONLY)

Percentage of Capital Costs	Frequency	Relative Frequency
0	39	.683
1-10	1	.018
10-20	3	.053
20-30	5	.088
30-40	7	.123
40-100	2	.035
Total	57	1.000

Source: Research Triangle Institute. 1988. Memo to EPA on responses to Section 114 survey letters.

Table 4-6 shows total operating subsidies as a percentage of total facility revenues. This is a crude measure of the extent to which facility operations receive support from government, either at the state or federal level. Only 63 of the 106 facilities in the current Section 114 survey database answered these questions. Of these 63 respondents, 75 percent reported receiving zero subsidy. Based on this rough measure, it appears that the owners of MWC facilities do not, in general, rely heavily on continuing direct payments from the state or federal government to cover budget shortfalls. Two facilities, however, reported their subsidy revenue was more than 90 percent of their total revenues.

Table 4-7 shows grants as a percentage of total capital costs. This percentage is a crude measure of the state and federal government support received by facility owners to cover their capital costs. Again, only a fraction of the facilities responding to the survey answered this question. Of the 57 facilities responding, 39 (68 percent) stated that they receive no grants. Again, based on this crude measure, it appears that facility owners do not rely heavily on support from the state and federal government to meet their capital costs, although a sizable minority (15.8 percent) received over 30 percent of their capitalization in the form of state and federal grants.

When a public entity collects MSW for disposal with either a private facility or a facility owned by another public entity it usually negotiates a long-term contract for disposal with the entity providing disposal. Private collection firms franchised by public entities also frequently have such long-term contracts. These MSW disposal contracts usually have provisions for passing on costs that arise due to circumstances outside the control of the disposal system operator. Requirements related to air emission control NSPSs most likely would fall under such provisions. As such, where tipping fees are used, the costs of regulation for an existing facility would be passed on to the collectors that hold long-term rights to dispose of MSW at that disposal site. Similar terms may also occur in contracts between private waste collectors and public entities.

Local public entities also participate in MSW management in their capacity as regulators of land use and guardians of public health and welfare. Siting and operation of private MSW disposal facilities are usually subject to local government review and approval. Successfully addressing local citizens' concerns has become very difficult because of awareness of both hypothesized and actual effects disposal facilities have on local property values, health, and the environment. Local fear and strident opposition to landfills and combustors are fairly commonplace (*Wall Street Journal*, Sept. 4, 1987). One, albeit remote, economic impact of the

NSPSs may be reduced costs of siting and building new MWC plants because local opposition will wane as new MWC plants emit fewer residuals into the atmosphere.

4.1.2 State Government

In recent years, states have taken a more active role in shaping the MSW management practices in their jurisdiction. While the nature and level of state initiatives vary tremendously, many states have become active in providing a framework for organizing and planning local MSW management (Kovacs, 1988). States most prominent in this area tend to be those confronting serious MSW management problems due to dense populations (because of the large amount of waste such populations generate and the limited space for disposal sites) and the vulnerability of their natural environment (e.g., states with limited water resources and/or high water tables).

Goddard (1975) notes that California and Connecticut were among the leaders in this regard, setting up a Solid Waste Management Board in California and the Connecticut Resource Recovery Authority in Connecticut in the early 1970s.

More recent examples include New York State's Department of Environmental Conservation, which issued solid waste rules covering liner requirements for landfills; disposal of combustor fly ash; and emission limits on particulates, dioxin, and nitrogen oxide for waste incinerators (*Solid Waste Report,* Sept. 12, 1988). In June 1988, Florida passed a solid waste law that, among other things, required each county to initiate a recycling program, set 1994 as the target date by which 30 percent of the State's waste would be recycled, established qualifications to be met by operators of waste management facilities, and required owners and operators of landfills to set fees to ensure the proper closure of landfills (*Solid Waste Report,* July 11, 1988).

Many other states have either passed legislation that is similar in intent to these examples or are seriously considering such legislation—for example, Massachusetts (Cowen, 1987). Table 4-8 summarizes state solid waste laws enacted in 1988. Of particular interest are the regulations regarding general solid waste management, mandatory source separation, and waste-to-energy facility requirements. Ohio's H592, signed June 24, 1988, effectively doubles solid waste disposal permitting fees and calls for a comprehensive state solid waste management plan (*Solid Waste Report,* October 17, 1988). In effect, states have become very active in establishing the terms and conditions under which local governments must operate as they seek to structure their local MSW management systems.

TABLE 4-8. STATE SOLID WASTE LAWS ENACTED IN 1988

ISSUES	AZ	CA	CT	FL	HI	IL	IA	LA	MD	MA	ME	MI	MN	NH	NJ	NY	OH	OK	PA	RI	TN	VA	WA	WI
General solid waste management				•					•				•		•	•	•	•	•					
Purchasing preferences for recyclables			•	•		•	•			•				•		•		•	•				•	•
RECYCLING: Waste reduction program requirements		•		•	•	•		•	•							•		•	•	•		•	•	
RECYCLING: Planning and goals				•		•			•			•				•	•	•	•					
RECYCLING: Study	•																				•	•		
RECYCLING: Mandatory source separation				•															•			•		
NONDEGRADABLES: Bans/ restrictions on use		•		•						•	•	•	•							•				
NONDEGRADABLES: Taxes				•																				
NONDEGRADABLES: Incentives to recycle				•			•											•						
Labeling of products made with recyclable/degradable material		•		•							•		•											•
Waste-to-energy facility requirements		•									•		•						•					

Source: *Solid Waste Report*, October 17, 1988

4.1.3 Federal Government

The Federal Government, by virtue of both legislation and regulation, influences solid waste management in a variety of ways. Sections of the Resource Conservation and Recovery Act of 1976 (RCRA), the National Energy Conservation Policy Act of 1978, and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 all address issues of solid waste and MSW management. Under RCRA and subsequent amendments, for example, regulations requiring stricter control of waste at sanitary landfills, referred to as Subtitle D regulations, have been proposed and procurement procedures aimed as fostering recycling initiated.

Two Federal actions that have been especially important to MWC activity have been the Public Utility Regulatory Policy Act of 1978 (PURPA) and the Tax Reform Act of 1986. Under PURPA regulations, independent small power generators have better opportunities, under more favorable financial terms, to provide electricity to electric utilities. This, in combination with higher electricity prices generally, has spurred the development of MWCs that co-produce steam and electric energy. The Tax Reform Act of 1986, on the other hand, has reduced the tax and financing advantages available to private owners of new MWCs (Hilgendorff, 1989). While Hilgendorff estimates that between 50 and 100 upcoming MWC projects are "grandfathered" under the Act, "most analysts agree that the eventual effect ... will definitely compel municipal ownership."

Recently, EPA has led a federal effort specifically aimed at reshaping the way in which solid waste is managed in the U.S. In its reports, *The Solid Waste Dilemma: An Agenda for Action Final Report* (1989d) and *Background Document* (1989e), EPA calls for "integrated waste management" in keeping with the following preferred hierarchy of processes:

- source reduction (including reuse of products),
- recycling of materials (including composting),
- waste combustion (with energy recovery), and
- landfilling.

The final report and supporting documents go on to discuss obstacles to establishing the integrated waste management system envisioned and options for overcoming those obstacles through information, demonstration, and incentive programs.

4.2 MSW DECISION MAKING

The design and operation of a MSW management system requires decision makers to make a number of choices. These choices are constrained by technical and economic factors and will have implications for generators and managers of solid waste as well as suppliers of inputs of MSW management services (e.g., labor services, MWC suppliers, owners of land) and area residents.

For example, governments must decide which institutional arrangement to use for waste collection and disposal. Depending on the institutional arrangements, public and private decision makers must choose the amount and type of solid waste to generate (the demand side) and disposal processes to provide—combustion, recycling, and landfilling (the supply side). For each process they must determine the appropriate location, scale, and design lifetime. Imposition of the NSPSs will likely affect these choices. To help analyze this effect, we now briefly discuss the objective(s) that guide the response of private and public decision makers.

4.2.1 Private Decision Making

In conventional economic analysis, households are utility maximizers and firms are profit maximizers. They are bound together by markets—market supply and demand balance competing interests given finite resources, limited technical knowledge, and institutional conditions, including the structure of the markets themselves (e.g., perfect competition, monopoly). This analysis assumes that the private components of most local solid waste management systems will follow the conventional economic paradigm. As described in Chapter 2, households and firms that generate waste respond to increases in the price of waste collection by reducing their amount of waste generated. The proportionate reduction may not be large, but if the price increase is large enough, the effect will be noticeable. By the same token, however, if cost increases in the MWC portion of the management system are not fully reflected in prices or tied to the amount of waste generated, there will be little or no change in waste generation attributable to the NSPSs beyond that associated with "income effects" due to changes in taxes.

Similarly, firms that collect, transport, and/or dispose of waste are assumed to respond to changes in the cost of production by adjusting their input mix to keep costs down and by passing as much of the remaining cost increase on to their customers (as price increases) as market conditions and contractual arrangements allow. In the case of a new MWC plant, the prospective owner has a broader set of available options for reducing cost, including changing the disposal technology selected and not building a plant at all. In the end, however, local market conditions must be seen by the prospective owner as supporting a disposal price that covers the minimum cost method of providing disposal services. The extent that MWC owners can raise prices and the degree to which this is accompanied by a change in the amount of waste combusted depends on the demand for combustion services in the local market. As noted in Chapter 2, this demand depends on the share of combustion services used, the availability of substitutes, and the demand of disposal services generally. While institutional conditions associated with local, state, or federal policies will affect these determinants of demand, in this analysis private parties accept such institutional conditions as given and make production and investment decisions so as to maximize profit or, equivalently in a competitive market, minimize the cost.

4.2.2 Government Decision Making

Government decision making is of particular concern in this analysis given the large role that government plays at every level, but especially the local level, in shaping MSW management systems. Theoretical and applied literature does not provide much positive guidance on the behavior of governments (e.g., Rubinfeld, 1987). On the other hand, normative literature on MSW management decision making, much of it aimed at decision making by public officials, often assumes that cost minimization, sometimes referred to a "project economics," is the implicit basis on which decisions regarding MSW management are reached. Consequently, this literature addresses methods and means by which the decision maker can make the correct, cost-minimizing choice (Robinson, 1986). Examples also include authors who aren't necessarily enthusiastic about conventional waste disposal options. Kirshner and Stern (1985) and the Institute for Local Self-Reliance (Morris, 1987) both couch their arguments against extensive MSW incineration and for recycling in cost-minimizing terms.

RTI contacted eight communities that had recently made decisions to build MSW combustors to learn their basis for selecting a particular disposal option and technology (Berry et al., 1988). While this was not a scientific survey, the individuals contacted in the public works or a similar department described cost as the over-riding consideration in the community's decision. The decision was subject to the conditions that they have some means of meeting their community's MSW disposal requirements and that this means is compatible with environmental and other considerations. For example, most said either that MWC was more economical than a landfill in their circumstances or that they couldn't get a permit to build a new landfill in their area because of environmental constraints. The exception to this was an individual who noted that the least costly MWC system was selected even though a landfill might have been a cheaper way to dispose of MSW per se because the community also had to provide steam to a public facility and, given the wider scope of the decision, a MWC system was most economical.

While this evidence is not absolute proof of the proposition, it seems sufficient to justify that local or municipal MSW system decision making represents cost minimization, subject to the constraint that all MSW must be collected and properly disposed. It differs from private decision making in that the minimum cost is assessed based on centralized enterprise of costs of various combinations of MSW management alternatives, some of which may not be feasible for a private firm due to institutional or financial constraints.

4.2.3 Cost Minimization

In this analysis cost-minimizing decision making is used as the basis for the enterprise cost and emission reduction estimates of Scenario I. In other words, the control options identified in the engineering analysis that supports this economic analysis were developed to meet the alternative emission standards at minimum cost, and we assume that private and public decision makers will select these control options for their new MWC plants after promulgation of the NSPSs. In Scenario II, the decision makers consider a broader range of choices, reviewing plant technology as well as control technology with the intent of minimizing the total system cost. Making quantitative impact estimates for Scenario II is complicated, however, because of both the different institutional and market conditions that characterize local waste management systems. Rather than make quantitative estimates for Scenario II in this analysis, we take advantage of a complimentary analysis of an even broader array of waste disposal choices (Mathtech, 1989) and use it to estimate economic impacts under Scenario III. In Scenario III, decision makers make investment decisions for solid waste disposal from among three MWC technologies and a landfill of appropriate size and revise their choices based on the new costs of control associated with the NSPSs for each of the MWC technologies.

CHAPTER 5
ANALYTICAL APPROACH TO ESTIMATION OF COST AND EMISSION IMPACTS

To estimate the impact of MWC New Source Performance Standards (NSPSs), estimated levels of new activity in relevant markets must be compared before and after the regulation. First we project baseline or "without NSPSs" conditions. Then we compare these conditions with five "with NSPSs" regulatory alternatives under three economic scenarios. As their names suggest, the regulatory alternatives represent the different regulatory designs under active consideration by EPA, and the economic scenarios represent varying degrees of market response to the NSPSs.

5.1 BASELINE PROJECTIONS

The baseline level of MWC activity depends on how much solid waste is generated and what other waste handling methods are available and in use, including landfills, materials recovery, self disposal, and littering. For this reason, we make baseline projections not only for solid waste combustion but also for solid waste generation and the amount of solid waste managed by other major methods.

5.1.1 Initial Conditions

We selected 1986 as the initial year (i) for baseline projections because it is the most recent year for which a wide variety of quantitative data on waste management activities are available. We used these data to build up a profile of 1986 solid waste flows (Q_{wi}) associated with MWCs and the major waste management options that are alternatives to combustion. This procedure is sometimes complicated because of differences in the definition and scope of the various source documents.

From the results of the 1986 landfill survey (EPA, 1988b) Westat estimated that a total of 189.4 million Mg of waste was landfilled in 1986. This estimate includes the estimated amount of municipal incinerator ash landfilled in 1986: 1.3 million Mg. We subtracted this value from the total because other estimates do not include incinerator ash. Thus, the Westat estimate of waste landfilled in 1986, net of municipal incinerator ash (Q_{li}), equals 188.1 Mg. This value makes up the first component of 1986 solid waste flows illustrated in Figure 5-1.

A recent Franklin Associates report (1988) provides useful information on 1986 municipal solid waste (MSW) flows. These flows are based on estimates of consumption activity and include some waste components that are not landfilled or combusted at a municipal incinerator (such as self-disposed materials, litter, and recycled materials) and exclude some

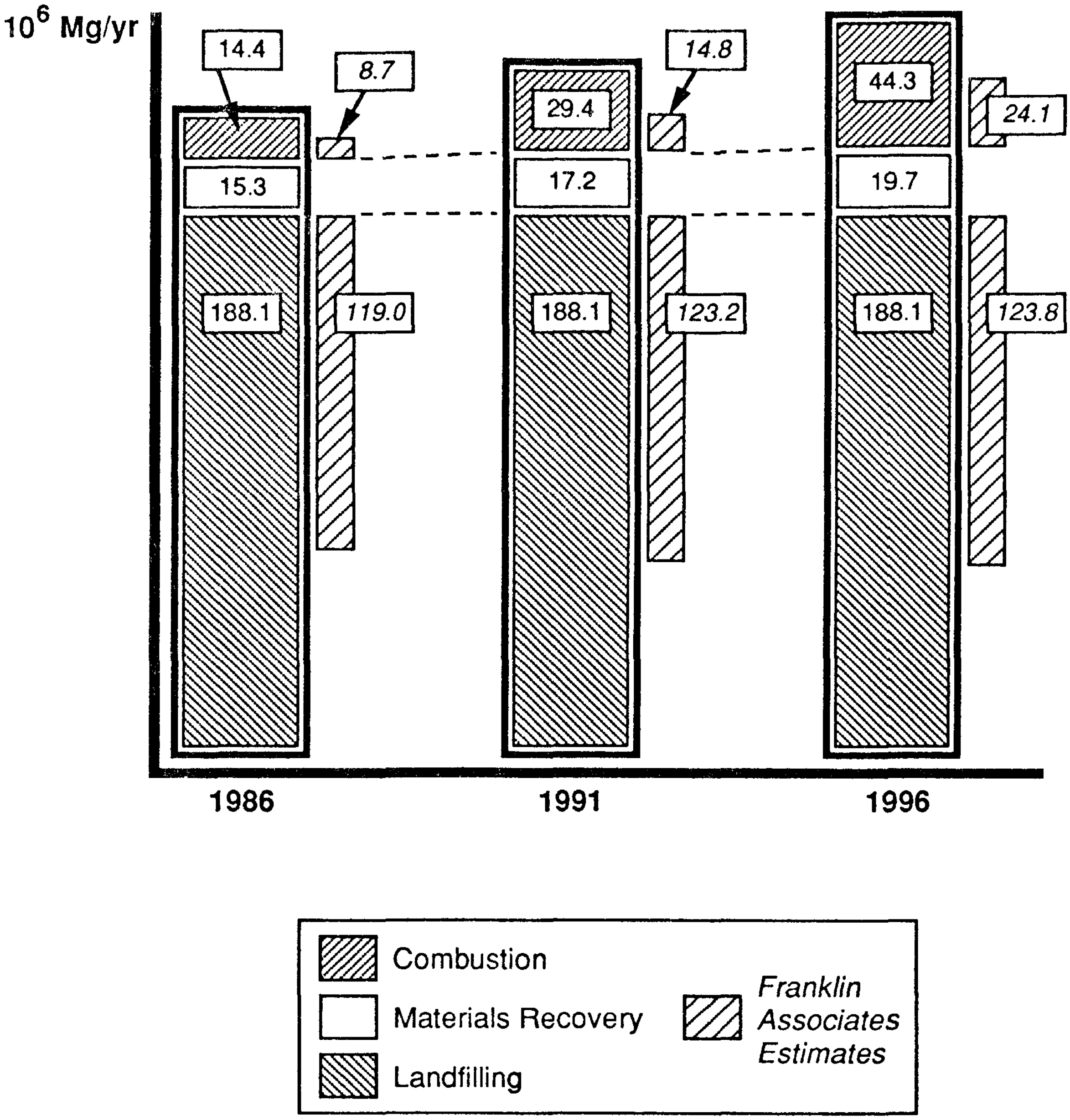


Figure 5-1. Solid Waste Flow Projections, 1986 through 1996

solid wastes that are landfilled and combusted (such as car bodies, sewerage sludge, industrial and commercial waste, construction wastes, and foreign import packing materials). Franklin Associates estimates that 143.0 million Mg of MSW (excluding municipal incinerator ash) was generated in 1986. They estimate the disposition of this MSW as follows: 15.3 million Mg of material recovery (recycling), 119.0 million Mg landfilled (net discards), and 8.7 million Mg combusted (by energy recovery facilities).

The Franklin Associates (1988) materials recovery estimate (Q_{mi}) is added to the waste flows represented in Figure 5-1. The Franklin Associates MSW flows to landfills and combustors are shown as components of the landfill and combustion flows estimated in Figure 5-1. These components are somewhat smaller than the corresponding landfill and combustion flows used to specify initial conditions in baseline. This is because landfills and combustors receive more solid waste than included in the definition of MSW used by Franklin Associates. Still, as Figure 5-1 shows, most waste flowing to these treatment technologies appears to originate as MSW.

The Radian census of existing municipal waste combustors (EPA, 1989b) is the primary source for our estimate of baseline solid waste flows to combustors in 1986. This census includes all combustors that burn MSW. We estimated waste flows to combustors by applying average capacity utilization factors to each identified combustor. These factors varied with the combustor technology (mass burn, modular, or RDF) and heat recovery capability as reported by the 1988-89 *Resource Recovery Yearbook* (Gould, 1988) and estimated in Radian's retrofit report (EPA, 1989b). We also adjusted combustor solid waste flows to account for the fraction of facilities that co-fired solid waste with another fuel. As a result of these calculations we estimate that combustors handled 14.4 million Mg of waste flow (Q_{ci}) in 1986. This is higher than the Franklin Associates estimate of MSW flows to combustors in 1986 partly because Franklin Associates only counts "energy recovery" facilities among its combustors.

Summing components as shown in Equation 5.1, total non-hazardous solid waste flow handled by landfills, recycling, and combustion in 1986 is estimated to be 218 million Mg.

$$Q_{wi} = Q_{li} + Q_{mi} + Q_{ci} \qquad (5.1)$$

This total, along with the component major waste handling methods, is the point of departure for baseline projections. As can be seen by Equation (5.1), our analysis does not specifically deal with littering and self-disposal even though our total waste generation estimates do include these components. These waste flows are even more difficult to estimate accurately and do not comprise a significant segment of the total waste stream. By the same token, we don't attempt to estimate or project changes in materials recycling of industrial or commercial waste that would otherwise be landfilled or ash from combustion, net of any ash sent to a dedicated ash landfill, that is landfilled as MSW.

EPA's goal for the nation is to incinerate 20 percent and to recycle 25 percent of the MSW stream by 1992 (EPA, 1989d). The projection of 44.3 and 19.7 million Mg in 1996 for combustion and recycling, respectively, amounts to 17.5 and 7.8 percent of the MSW stream. The projection used here is based on a slightly different definition of the composition of MSW and is only for analytical purposes; it should not be interpreted as an alternative goal. To the extent the nation recycles more than 7.8 percent of MSW in 1996, there will be a reduced demand for MWC and landfill services, and the nationwide costs and emission reductions associated with the NSPSs will be smaller. On the other hand, to the extent the nation burns more than 17.5 percent of MSW in 1996, the demand for MWC services will be larger and the nationwide costs and emission reductions associated with the NSPSs will be larger. The costs and emissions associated with landfills are not analyzed here.

5.1.2 Projections

The baseline projection used in this analysis draws heavily on the assumptions and projections made by Franklin Associates (1988). In summary, we project future total waste flows and associated flows to landfills and materials recycling. Projected landfill and materials recycling flows are subtracted from the projected total to provide a projection of the flow of waste to combustors in 1996. This procedure is characterized in Equation (5.2), where the p subscript represents baseline projections.

$$Q_{cp} = Q_{wp} - (Q_{mp} + Q_{lp}) \qquad (5.2)$$

We select 1996 because of the five-year period of analysis adopted for this report. All plants that begin construction within five years after publication of the NSPSs in the *Federal Register* (anticipated for late 1989) are expected to be operating in 1996. Plants under construction before the date the NSPSs are proposed will be subject to a separate regulation (MWC Guidelines) to be published at the same time as the NSPSs.

Franklin Associates assumes that "waste landfilled will be relatively constant." Our baseline projection actually fixes landfilled waste at 188.1 Mg per year. Materials recycling of MSW is projected to grow at the annual rates estimated by Franklin Associates, reflecting "no dramatic changes in current practices." This amounts to 19.7 million Mg. in 1996. The growth in total waste flows is based on the annual growth rates in MSW gross discards projected by Franklin Associates In making its projection, Franklin Associates relied on documentation of "historical production (or consumption) of materials and products that enter the municipal waste stream."

The total solid waste flows projected for the baseline in this analysis (using Franklin Associates' projected growth rate for gross discards) is 252.1 million Mg. Equation (5.2) gives a baseline projection of waste combusted in 1996 of 44.3 million Mg. These projections are shown in Figure 5-1 along with the comparable projections made by Franklin Associates for MSW flows to landfills and combustors. Figure 5-1 also shows projections of total waste flows and its components for 1991, based on the procedures described above and that apply to the MWC Guidelines. These data are denoted by the subscript g in Equation (5.3) below.

5.1.3 Baseline Combustion

As shown in Equation (5.3), the difference in the projection of waste flows combusted in 1996 and those in 1991 is the waste flow to combustors, Q_{cn}, that is affected by the NSPSs.

$$Q_{cn} = Q_{cp} - Q_{cg} \tag{5.3}$$

The baseline projection of waste flow to affected combustors is estimated to be 15.0 million Mg/year.

Using baseline projections of waste flows affected by the NSPSs, we constructed estimates of affected MWC capacity by MWC technology and NSPSs model plant category. First we adjusted the waste flows implicit in the model NSPSs plant description and Radian's cost report (EPA, 1989c) to reflect the capacity utilization estimates described above and plants that co-fire with materials other than MSW. Then we allocated projected baseline waste flows, Q_{cn}, to each of the 12 model NSPSs plant categories in proportion to the waste flow shares implicit in Radian's report. Table 5-1 displays the allocation of these flows to combustor technologies and model NSPSs plant categories. Table 5-1 also presents corresponding information on the total MSW capacity for each NSPSs model plant category.

TABLE 5-1. BASELINE PLANT CAPACITY AND WASTE FLOW ESTIMATES FOR MWC PLANTS SUBJECT TO NSPSs

Model Plant Number	Model Plant Description	Capacity[a] (10^6 Mg/yr)	Waste Flow[b] (10^6 Mg/yr)
1	MB/WW (small)	1.11	0.64
2	MB/WW (mid-size)	1.93	1.63
3	MB/WW (large)	6.33	5.36
4	MB/REF	0.54	0.45
5	MB/RC	1.12	0.95
6	RDF	3.57	2.95
7	RDF/CF	2.19	0.91
8	MOD/EA	0.27	0.22
9	MOD/SA (small)	0.03	0.02
10	MOD/SA (mid-size)	0.24	0.19
11	FBC/BB	0.61	0.51
12	FBC/CB	1.35	1.12
	TOTAL	19.29	14.95

[a]Capacity estimates based on Radian's model plants description and cost report (EPA, 1989c).
[b]Waste flow estimates calculated based on the annual operating hours reported in Table 3-3. For 9 of the model plants these hours reflect the average capacity utilization, by plant type, reported in the *1988-89 Resource Recovery Yearbook* (Gould, 1988). Allowance is made for increased downtime for model plants 1 and 9; and allowance is also made for model plant 7 which co-fires 50 percent wood.

Figure 5-2 compares the baseline projections of future combustion developed here with projections recently made by other organizations. Most alternative projections are made in terms of capacity, so that is the basis for the comparison adopted in Figure 5-2. The different projections are adjusted for this comparison to reflect a common scope—that of the Radian combustor profile. Figure 5-2 shows that projections of combustor capacity for 1996 range from Franklin Associates' estimate of 26.3 million Mg to Radian's estimate of 104.7 million Mg. In comparison to the alternative projections of MWC capacity made by other organizations (excluding Radian), the "Baseline" projection used for this report exceeds all but the Radian estimates and is 50 to 100 percent higher than the two lower projections.

5.2 SCENARIOS

Analyzing the economic impacts of MWC NSPSs under each regulatory alternative is especially challenging because of the MSW industry's complicated organizational structure and decision-making policies. Even assuming that cost minimization is a primary decision criterion, it is difficult to predict how public and private decision makers—uncertain about the future, constrained by a wide variety of institutional considerations, and examining a multiplicity of interrelated waste management options—will respond to tighter air emission NSPSs on

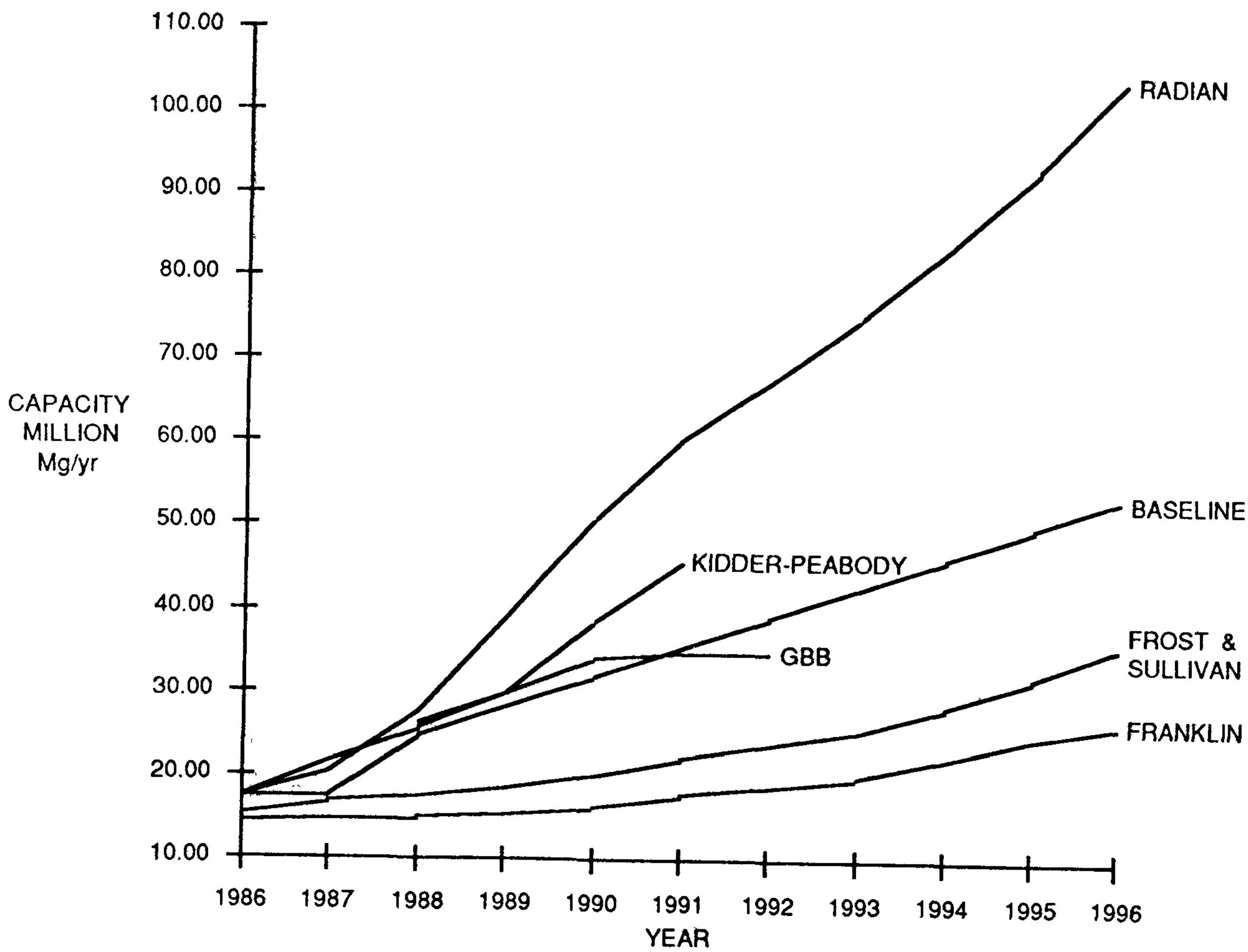


Figure 5-2. Comparison of MWC Capacity Projections, 1986 to 1996

combustors. Will they adopt the air pollution control devices (APCDs) designated in the engineering analysis for each model plant? Or, confronted by the prospect of potentially expensive modifications to their new plant, will they review their entire waste management program and devise an alternative strategy in light of the NSPSs?

Because of the uncertainty surrounding response to NSPSs, three economic impact scenarios are considered.

Scenario I	No substitution; employ APCD modification as specified in the model plant analysis.
Scenario II	MWC substitution; different MWC technology replacement for baseline MWC where feasible and cost-minimizing.
Scenario III	Greater substitution; landfill or different MWC technology allowed to replace baseline MWC.

These scenarios, applied to each of the regulatory alternatives, are analyzed using the model plants introduced in Chapter 3. The scenarios differ in the extent to which decision makers substitute away from the projected level and mix of baseline projections of new combustion activity. Scenario I assumes that there is no such substitution: all plants projected in the baseline will be built as planned. These plants, as represented by their respective model plants, are assumed to be built as planned except that they incorporate the additional APCDs identified in the cost report (EPA, 1989c) for each regulatory alternative. Of course, these changes also impose additional cost on the plant and reduce plant emissions.

Scenario II assumes that decision makers consider substituting a different MWC plant for a plant affected by the NSPSs. In this scenario substitution is based on cost and capacity comparisons among the NSPSs model plants. In Scenario II, then, baseline levels of MSW combusted remains the same, but the mix of MWC plants changes. This change reduces the cost of the regulatory alternatives relative to those of Scenario I. In this report, we don't provide quantitative estimates of these costs and any associated emission reductions of each regulatory alternative for Scenario II; we examine in a qualitative way the impact of NSPSs when decision makers include the option of building a different type of MWC in place of the one originally planned. To a certain extent, however, this substitution is incorporated in Scenario III, for which quantitative estimates of impact are provided.

Under Scenario III we examine the impact of NSPSs when decision makers include increased landfilling as well as other MWCs, as alternatives to the original NSPSs plant. Unlike Scenarios I and II, then, Scenario III admits the possibility that the NSPSs will reduce the amount of MSW combusted relative to the baseline. To estimate the extent of such substitution under each regulatory alternative, an econometric analysis of historic disposal choice was undertaken (Bentley and Spitz, 1989). RTI used the sensitivity of disposal choice to cost increases as estimated by the econometric model to project the extent to which baseline estimates of the level and mix of combustion would change in response to the cost increases associated with the regulatory alternatives. The revised forecast of affected plants is then used as the basis for projecting national cost impacts using the model plant method described above for Scenario I.

5.3 REGULATORY ALTERNATIVES

Six conditions are relevant to estimating the economic impacts of the NSPSs: the baseline and five regulatory alternatives. The baseline conditions that establish the number and type of affected NSPSs plants and the amount of MSW combusted in these plants are described in the previous sections of this chapter. The baseline conditions described here refer to control technologies and emission levels for MWC plants in the absence of the NSPSs. The costs of these baseline control technologies have already been presented for model plants in Chapter 3. The five regulatory alternatives considered in this analysis specify the emission levels the affected plants would have to comply with.

Table 5-2 outlines the five regulatory alternatives for the NSPSs. The NSPSs would impose varying emissions limits on MWCs. Air emissions affected include polychlorinated dibenzo-*p*-dioxins and dibenzofurans (CDD/CDF), carbon monoxide (CO), particulate matter (PM), hydrogen chloride (HCl), sulfur dioxide (SO_2), and lead (Pb). In certain circumstances the residue remaining after combustion is changed due to the APCD changes.

Radian has estimated baseline emission levels in the NSPSs model plant description and cost report (EPA, 1989c). These baseline emissions are the emissions produced if there are no additional controls or changes in operating conditions at the affected facilities. The analysis of regulatory impacts requires these data on the emission levels associated with the baseline and the regulatory alternatives for affected facilities.

TABLE 5-2. MAXIMUM EMISSIONS BY REGULATORY ALTERNATIVE

Regulatory Alternative	Control Parameters	Plant Capacity (Mg per day) Small ≤225	Large >225
I	CDD/CDF	300 ng/Nm^3	300 ng/Nm^3
	PM	0.18 g/dscm	0.02 g/dscm
	Temperature[a]	230 °C	230 °C
IIA	CDD/CDF	300 ng/Nm^3	75 ng/Nm^3
	PM	0.18 g/dscm	0.02 g/dscm
	Temperature[a]	230 °C	175 °C
IIB	CDD/CDF	75 ng/Nm^3	75 ng/Nm^3
	PM	0.02 g/dscm	0.02 g/dscm
	Temperature[a]	175 °C	175 °C
III	CDD/CDF	300 ng/Nm^3	5 ng/Nm^3
	PM	0.18 g/dscm	0.02 g/dscm
	Temperature[a]	230 °C	150 °C
IV	CDD/CDF	75 ng/Nm^3	5 ng/Nm^3
	PM	0.02 g/dscm	0.02 g/dscm
	Temperature[a]	175 °C	150 °C

[a]Outlet temperature at PM control device.

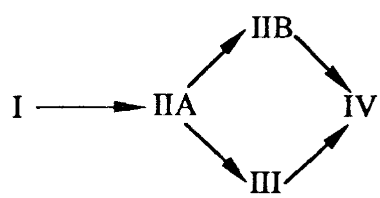
Source: Radian. 1989. *Background Paper, Municipal Waste Combustors.* Prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

Under each of the five regulatory alternatives, each model plant is associated with one of three engineering control options examined by Radian (EPA, 1989c). The three control options consist of various combinations of four types of control technologies. The technologies followed by the emissions they are designed to control are listed below:

- Good combustion practice (GCP)—CDD/CDF and Pb
- Flue gas temperature reduction—CDD/CDF
- Particulate matter (PM) control—PM
- Acid gas control (dry sorbent injection/ESP or spray dryers/fabric filters)—HCl, SO_2, and CDD/CDF

PM control is further defined as moderate, good, or best depending on the level of emission reduction required to meet the relevant regulatory alternative. Acid gas control is also described as good or best in reference to the level of emissions allowed under each regulatory alternative. Good acid gas control is achieved through the use of dry sorbent injection. Reduction of emissions to the level required for best acid gas control is achieved through spray dryers and fabric filters.

The levels of control reflected by the regulatory alternatives do not follow a straight forward progression of least to most stringent when moving from Regulatory Alternative I through Regulatory Alternative IV. Compared to IIA, Regulatory Alternative IIB imposes no further control over large plants (greater than 225 Mg/day design capacity) but tightens controls over small plants (less than or equal to 225 Mg/day design capacity). Moving from IIA to III, on the other hand, imposes no further control for small plants while bringing greater control over large plants. The two paths of least to most stringent are characterized below:



5.3.1 Baseline Emissions

Baseline combustion practice and emission rates vary from plant to plant. In the baseline, all model plants meet the federal standards, which limit PM emissions to a maximum of 0.18 g/dscm for MWC plants with the exception of plants with design capacity of 45 Mg/day or less. As a result, all model plants in the analysis limit PM emissions to 0.18 g/dscm or less in the baseline except model plant 9 which has design capacity of 45 Mg/day.

5.3.2 Regulatory Alternative I

Regulatory Alternative I is the least stringent of all the regulatory alternatives. Under this alternative, all plants must achieve GCPs and reduce flue gas temperatures to 230 °C. CDD/CDF emissions would be reduced to 300 ng/Nm^3 with these controls in place. Small plants are required to practice moderate PM control, limiting PM emissions to 0.18 g/dscm, and large plants are required to achieve best PM control, limiting PM emissions to 0.023 g/dscm. No acid gas control is required for plants of any size under this alternative.

5.3.3 Regulatory Alternative IIA

Regulatory Alternative IIA is the next most stringent alternative and also requires GCPs for all plants. Controls for small plants are no different under Regulatory Alternative I than IIA.

Moderate PM control, 230 °C flue gas temperatures, and no acid gas control are required of smal plants. However, large plants are required to further reduce flue gas temperatures to 175°C, achieve good acid gas control through the use of add-on control equipment, and practice best PM control. This has the affect of reducing CDD/CCF to 75 ng/Nm^3 and PM to 0.023 g/dscm. HCl and SO_2 emissions are reduced 80 and 40 percent over the baseline, respectively.

5.3.4 Regulatory Alternative IIB

One progression from least to most stringent regulation is characterized in the move from IIA to IIB. Regulatory Alternative IIB has the same controls for large plants and more stringent controls for small plants when compared to Regulatory Alternative IIA. As with Regulatory Alternative IIA, GCPs, 175 °C flue gas temperatures, best PM control, and good acid gas control are required of large plants. Small plants, however, must also reduce flue gas temperatures to 175 °C, achieve good acid gas control, and practice best PM control under Regulatory Alternative IIB. These controls reduce CDD/CDF to 75 ng/Nm^3 and PM to 0.023 g/dscm. An 80 percent reduction in HCl and a 40 percent reduction in SO_2 over baseline emission levels would result from these control measures.

5.3.5 Regulatory Alternative III

Another progression from least to most stringent occurs when moving from IIA to III. Regulatory Alternative III imposes the same controls on small plants as IIA while enforcing tighter controls on large plants. As before, all plants are required to achieve GCPs but small plants are only required to practice moderate PM and maintain 230 °C flue gas temperatures. No acid gas control is required for small plants under this alternative. Large plants must meet the most stringent standards imposed in the progression thus far including GCPs, 150 °C flue gas temperatures, best PM control, and best acid gas control. Emissions for large plants are reduced to 5 ng/Nm^3 for CDD/CDF and 0.023 g/dscm for PM. HCl and SO_2 emissions are reduced 97 and 90 percent over the baseline, respectively.

5.3.6 Regulatory Alternative IV

Regulatory Alternative IV is the most costly and the most stringent. Both small and large plants are required to practice GCPs and achieve best PM control. Good acid gas control and flue gas temperature reduction to 175 °C are required of small plants under this alternative. Large plants must achieve best acid gas control and flue gas temperature reduction to 150 °C. Emissions for large plants are identical to those under Regulatory Alternative III, and emissions for small plants are identical to those under Regulatory Alternative IIB for the same size category.

The technologies employed to control emissions are listed in Table 5-3. Table 5-4 identifies the control option described in the Radian cost report (EPA, 1989c) used for each plant capacity range as applied to each regulation. For example, large plants can meet their emission limits under Regulatory Alternative I using Control Option 1. Therefore, data on costs and emissions for large plants under Regulatory Alternative I are for Control Option 1.

TABLE 5-3. AIR POLLUTION CONTROLS BY REGULATORY ALTERNATIVE

	Plant Capacity (Mg per day)	
Regulatory Alternative	**Small ≤225**	**Large >225**
Baseline	GCPs[a] Moderate or no PM[b]	GCPs[a] Moderate or good PM
I	GCPs[c] Moderate PM[d]	GCPs Best PM
IIA	GCPs Moderate PM	GCPs Good Acid Gas[e] Best PM
IIB	GCPs Good Acid Gas Best PM	GCPs Good Acid Gas Best PM
III	GCPs Moderate PM	GCPs Best Acid Gas[f] Best PM
IV	GCPs Good Acid Gas Best PM	GCPs Best Acid Gas Best PM

[a]Model-plant specific.

[b]All 111(b) model plants meet Industrial Boiler Standards in the baseline requiring all plants with design capacity over 45 Mg/yr to limit PM emissions the level required under moderate PM control. All small plants with the exception of model plant #9 (45 Mg/day capacity) meet this limit for PM emissions in the baseline.

[c]Good combustion practices (GCPs) include proper design and operation of the combustor. Exhaust gas temperature control is also included in all alternatives with GCPs.

[d]"Particulate matter (PM)" control levels are shown in Table 5-2.

[e]Good Acid Gas control reduces emissions through the use of dry sorbent injection.

[f]Best Acid Gas control reduces emissions through the use of spray dryers and fabric filters.

Source: Radian. 1989. *Background Paper, Municipal Waste Combustors*. Prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

TABLE 5-4 CONTROL OPTIONS BY NSPSs MODEL PLANT FOR EACH REGULATORY ALTERNATIVE

Model Plant #	Model Plant Type	Regulatory Alternative I	IIA	IIB	III	IV
1	MB/WB (small)	Baseline	Baseline	#2	Baseline	#2
2	MB/WW (mid-size)	#1	#2	#2	#3	#3
3	MB/WW (large)	#1	#2	#2	#3	#3
4	MB/REF	#1	#2	#2	#3	#3
5	MB/RC	#1	#2	#2	#3	#3
6	RDF	#1	#2	#2	#3	#3
7	RDF/CF	#1	#2	#2	#3	#3
8	MOD/EA	Baseline	Baseline	#2	Baseline	#2
9	MOD/SA (small)	#1A[a]	#1A	#2	#1A	#2
10	MOD/SA (mid-size)	Baseline	Baseline	#2	Baseline	#2
11	FBC/BB	#1	#2	#2	#3	#3
12	FBC/CB	#1	#2	#2	#3	#3

[a]Control option #1A appears in parentheses in EPA (1989c).

Sources: U.S. Environmental Protection Agency. 1989c. *Municipal Waste Combustors—Background Information to Proposed Standards: 111(b) Model Plant Description and Costs of Control.* EPA-45013-89-27b.

Radian Corporation. 1988b. Memorandum to U.S. Environmental Protection Agency, August 30.

5.4 COST AND EMISSION REDUCTION ESTIMATION

5.4.1 Scenario I: No Substitution

In this scenario two assumptions are made: (1) model plants are representative of the many segments of the MWC industry affected by the NSPSs and (2) decision makers in these industry segments will, on average, respond to each regulatory alternative by modifying their MWC plant in the manner described by the model plant cost report (EPA, 1989c). Figure 5-3 depicts the second assumption of Scenario I. Any model NSPSs plant would incinerate Q_{mwc} Mg of MSW per year at a baseline cost of C^B_{mwc} per Mg MSW. Upon promulgation of the NSPSs, the plant owners would undertake the equipment and operating changes necessary to meet the NSPSs as estimated in the cost report (EPA, 1989c). The associated capital and operating costs incurred by the operator become the basis for estimation of the economic impact of the NSPSs under Scenario I.

For example, if the expenditures necessary to meet Regulatory Alternative I at this model plant increase the per-Mg MSW cost of operation to C^I_{mwc}, the annualized cost of the regulation (from the producer's point of view) is the cross-hatched area of Figure 5-3. If Regulatory

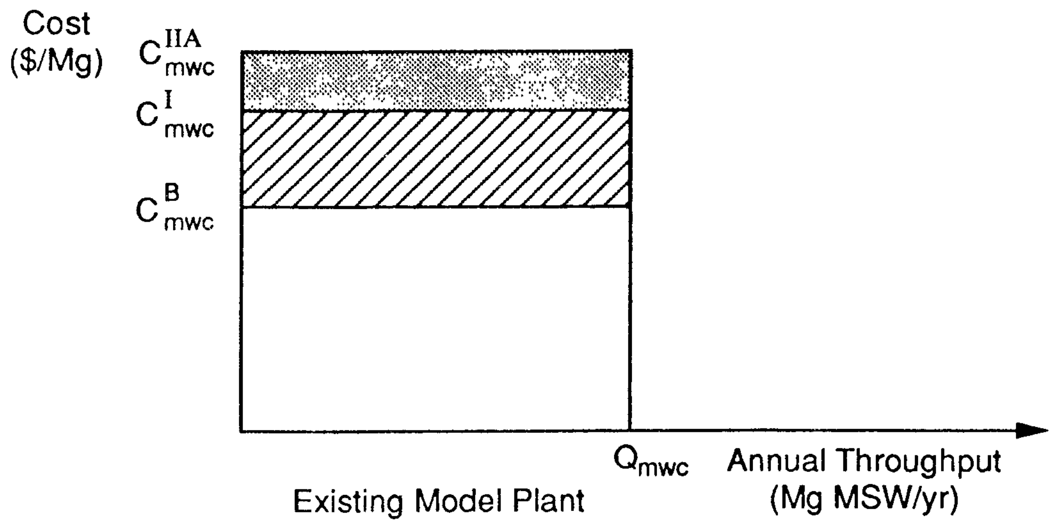


Figure 5-3. Municipal Waste Combustion Response under Scenario I: No Substitution

Alternative IIA requires more stringent control, the cost per Mg of MSW may rise to C^{IIA}_{mwc}, and the incremental cost of Regulatory Alternative IIA relative to Regulatory Alternative I is the shaded area of the diagram. The total cost of this regulation relative to the baseline is the sum of the cross-hatched and shaded areas of Figure 5-3; it is this latter cost that we report as this plant's contribution to the annualized cost of Regulatory Alternative IIA.

In Scenario I then, the assumption is that the MWC decision makers adopt the controls (and experience the costs) specified in the cost report (EPA, 1989c). In economic terms this is equivalent to specifying the absence of any more attractive substitution possibilities for meeting the emission requirements of the NSPSs. We also assume a perfectly inelastic demand for the services each model plant provides. This could be due either to inelastic demand per se or an institutional arrangement that does not allow any increase in costs to be passed along directly to waste collectors or, ultimately, to waste generators. Both are extreme assumptions when applied to all affected plants and probably result in some overestimation of the costs of regulatory alternatives under Scenario I. These same assumptions also allow us to use the model plant emission reductions estimated in the cost report to estimate incremental and total emission reductions for each regulatory alternative.

Radian provided basic capital cost, operating cost, and emissions data for the 12 model plants under baseline and controlled conditions. Using these data, together with baseline estimates of the amount of MWC capacity in each model plant category, we scaled model plant costs and emission reductions to cost and emission reduction estimates for each model plant category. The scale factors represented the number of model plants necessary to match the amount of MSW estimated to be handled by existing plants in that model plant category. Summing over the 12 model plant categories results in a national measure of cost or emission reductions. We also used the scale factors to estimate the number of plants in each model plant category as well as the total number of plants that will be subject to the NSPSs. Based on the scaling factors are shown in Table 5-5, approximately 67 MWC plants will be subject to the NSPSs.

5.4.2 Scenario II: MWC Substitution

When published, the NSPSs will be specified as emission limits, without reference to a specific abatement technology. This permits owners of prospective NSPSs plants to consider alternatives to the emission control approach selected in the engineering analysis, especially if these alternatives reduce the cost of disposing of MSW. In Scenario II the model plant cost data

TABLE 5-5. SCALING FACTORS USED TO OBTAIN SCENARIO I NATIONAL COST ESTIMATES[a]

Model Plant #	Model Plant Type*	Model Plant Capacity (Mg/day)	Scenario I Scaling Factors[b,c]
1	MB/WB (small)	180	16.81
2	MB/WW (mid-size)	730	7.28
3	MB/WW (large)	2,040	8.49
4	MB/REF	450	3.24
5	MB/RC	950	3.24
6	RDF	1,810	5.39
7	RDF/CF	1,810	3.31
8	MOD/EA	220	3.35
9	MOD/SA (small)	45	1.80
10	MOD/SA (mid-size)	90	7.13
11	FBC/BB	820	2.06
12	FBC/CB	820	4.54
	TOTAL		66.64

[a] Scenario III scaling factors differ with each regulatory alternative.

[b] These scaling factors are based on the annual operating hours reported in Table 3-3. For 9 of the model plants these hours reflect the average capacity utilization, by plant type, reported in the *1988-89 Resource Recovery Yearbook* (Gould, 1988). Allowance is made for increased downtime for model plants 1 and 9; and allowance is also made for model plant 7 which co-fires 50 percent wood.

[c] These scaling factors are used to estimate the number of MWC plants subject to NSPSs under Scenario I.

developed for the economic impact analysis could be used to to examine whether, for each model plant, constructing an alternative MWC technology that meets the emission limits would be less costly overall.

Such an approach was used for the MWC Guidelines economic impact analysis (RTI, 1989). We do not make quantitative impact estimates based on such a method in this impact analysis for two reasons. First, new technologies such as RDF and FBC systems are much more integral to the NSPSs baseline, and considerable uncertainty still surrounds their cost and performance. Second, Scenario III impact estimates are to be quantified, and these estimates embody the MWC technology substitution identified with Scenario II.

5.4.3 Scenario III: MWC/Landfill Substitution

The point of departure for the Scenario III analysis is a report by Bentley and Spitz (1989) on solid waste disposal choice. The report used recent data (1980 to 1986) on actual choices to build either new landfills or three types of new MWC plants (mass burn, modular, and RDF) to estimate a relationship between these choices and features of both the community and technology. Bentley and Spitz used engineering cost data from the Radian retrofit study (EPA, 1989b), plant characteristics data from the Radian cost report (EPA, 1989c), and financial and operating parameters developed by RTI for this analysis to estimate the cost of new MWC technologies as a function of plant capacity. They obtained data on landfill characteristics from an EPA landfill survey (EPA, 1988b) and landfill costs from EPA's Office of Solid Waste and its draft regulatory impact analysis of RCRA Subtitle D regulations on municipal waste landfills (Temple, Barker, and Sloan, Inc. et al., 1987). These data were combined with site information on population density, educational attainment of residents, and manufacturing employment and used to make econometric estimates of the likelihood of choosing one or the other solid waste disposal technology given the cost, plant, and site characteristics.

Bentley and Spitz provided the results of their analysis to RTI in form of a spreadsheet that uses the estimated choice equations to predict solid waste disposal technology with changing costs of landfills and MWC technologies. RTI modified this spreadsheet by inserting estimates of the average increase in landfilling costs due to Subtitle D regulations as a function of landfill solid waste flows. These cost estimates are based on data contained in the draft economic impact analysis for Subtitle D landfill regulations, adjusted for the financial parameters used in this analysis for public ownership. The waste flow shares estimated for each of the disposal technologies both before and after the inclusion of Subtitle D costs for landfills are shown in Table 5-6. These shares for the landfill, mass burn, modular, and RDF disposal options are denoted by s_l', s_b', s_m', and s_r', respectively. RTI then added the estimates of the cost of control for each regulatory alternative to the cost the MWC technologies and obtained revised estimates of the share of waste flows processed by the four disposal options. These revised share estimates are denoted s_l, s_b, s_m, and s_r. These changes in shares are used in Scenario III to estimate the marginal change in solid waste disposal choice due to the NSPSs.

TABLE 5-6. ESTIMATED WASTE FLOW SHARES

Technology	Before Inclusion of Subtitle D Costs	After Inclusion of Subtitle D Costs
Mass Burn	13.79%	15.24%
Modular	5.94%	6.49%
Refuse-Derived Fuel	8.02%	8.94%
Landfill	72.25%	69.34%
TOTAL	100%	100%

Source: Bentley, Jerome T. and William Spitz. 1989. *A Model of the MSW Choice Decision.* Prepared for the U.S. Environmental Protection Agency. Princeton, NJ: Mathtech Incorporated.

In order to use this share information, however, one needs estimates of the baseline level of affected waste flows for both MWCs affected by NSPSs and landfills that would filled in the same time frame. We obtained the MWC waste flows from the baseline allocation of flows to model plants displayed in Table 5-1 and derived from information on planned MWC plants. We obtained estimates of landfill waste flows subject to disposal choice from Westat's analysis of the remaining capacity and waste flow rates obtained from the landfill survey data (EPA, 1988b). If a landfill was scheduled to be filled in the period of analysis (1992-1996), we assumed that disposal of that amount of waste was subject to a new waste disposal choice. These estimated waste flows are shown in Table 5-7. We denote these initial values of waste flows subject to a disposal choice by Q_{ln} for landfills and Q_{bn}, Q_{mn}, and Q_{rn} for the respective combustor technologies.[1] When summed, these baseline waste flows subject to disposal choice equal Q_n (72.5 million Mg).

TABLE 5-7. ESTIMATED WASTE FLOWS SUBJECT TO DISPOSAL CHOICE BY TECHNOLOGY AND REGULATORY ALTERNATIVE (10^6 Mg/yr)

Technology	Baseline	Regulatory Alternative				
		I	IIA	IIB	III	IV
Before Adjustment for Constant Total Waste Flow						
Mass Burn	9.03	8.96	6.65	6.61	5.87	5.83
Modular	0.43	0.39	0.46	0.46	0.49	0.48
RDF	3.86	3.77	2.20	2.20	1.84	1.84
Landfill	59.14	59.93	65.43	65.52	66.91	66.99
TOTAL	72.45	73.05	74.74	74.78	75.10	75.15
After Adjustment for Constant Total Waste Flow						
Mass Burn	9.03	8.89	6.45	6.40	5.67	5.62
Modular	0.43	0.38	0.44	0.44	0.47	0.47
RDF	3.86	3.74	2.13	2.13	1.77	1.77
Landfill	59.14	59.44	63.43	63.48	64.55	64.59
TOTAL	72.45	72.45	72.45	72.45	72.45	72.45

[1] Data on FBC plant parameters and costs were not available in time to be included in Bentley and Spitz' analysis. Furthermore, there were virtually no FBC combustors operating in period over which historic data were collected. Consequently, FBC technology is not included in the Scenario III analysis.

Using ratios of the waste flow share estimates derived from Bentley and Spitz's choice equations, we then made an initial adjustment in the components of waste flows subject to disposal choice. Equation (5.4) shows this adjustment and the sum of initially adjusted values, Q_n'.

$$Q_{ln}\,(s_l''/s_l') + Q_{bn}\,(s_b''/s_b') + Q_{mn}\,(s_m''/s_m') + Q_{rn}\,(s_r''/s_r') = Q_n' \qquad (5.4)$$

As this equation shows, application of these shares adjusts waste flows going to new landfills or MWC plants in proportion to the change in share estimated by Bentley and Spitz's choice analysis. If, for example, the costs of a regulatory alternative increase the choice of modular combustors so that the modular share of waste flows in the historic data set increased, the modular combustor's share of waste flows subject to disposal choice in the period of the NSPSs analysis is estimated to increase proportionately.

One difficulty with this particular method is that Q_n' (the initially adjusted value) does not necessarily equal Q_n (the baseline flows subject to disposal choice). Since we assume that all the solid waste that was subject to a new disposal choice has to be disposed of in some way, we make a final adjustment by multiplying the waste flows estimated by using the share ratios s"/s' of Equation (5.4) by the ratio Q_n/Q_n'. These revised waste flows are the estimated waste flows for each technology used in Scenario III. We estimated a new set of waste flows for each regulatory alternative based on the new waste flow share estimates derived when the estimated costs of control for that regulatory alternative are introduced into the choice equations. These are denoted Q_{lI}, Q_{bI}, Q_{mI}, and Q_{rI} for Regulatory Alternative I; Q_{lIIA}, Q_{bIIA}, Q_{mIIA}, and Q_{rIIA} for Regulatory Alternative IIA; etc. These estimated waste flows for each technology and each regulatory alternative are also shown on Table 5-7.

In the final steps of Scenario III, RTI took the estimates of waste flows for each MWC technology and allocated them to model plants using that same MWC technology. We made this allocation proportional to the Scenario I baseline waste flows for that technology going the particular model plant. For example, Scenario III mass burn waste flows were allocated to mode plants that used mass burn technology and the waste flows estimated for a given model plant were based on that model plant's share of mass burn waste flows in the Scenario I baseline. These flows were then used to estimate the number of model plants under each regulatory alternative of Scenario III (see Table 5-8). We then applied the cost and emission reduction estimates for the model plants to obtain the national cost and emission reduction estimates for Scenario III.

TABLE 5-8. NSPSs MODEL PLANT NATIONAL WASTE FLOWS AND SCALING FACTORS [a,b]

Model Plant Number	Model Plant Description	Model Plant Waste Flow (Mg/day)	Scenario I Scaling Factor	Scenario I Total Waste Flows (10^6 Mg/yr)	Scenario III Scaling Factor	Scenario III Total Waste Flows (10^6 Mg/yr)
Regulatory Alternative I						
1	MB/WW (small)	104	16.81	0.64	16.54	0.62
2	MB/WW (mid-size)	615	7.28	1.63	7.16	1.61
3	MB/WW (large)	1,730	8.49	5.36	8.36	5.27
4	MB/REF	384	3.24	0.45	3.18	0.45
5	MB/RC	807	3.24	0.95	3.18	0.94
6	RDF	1,500	5.39	2.95	5.22	2.86
7	RDF/CF	750	3.31	0.91	3.21	0.88
8	MOD/EA	178	3.35	0.22	3.01	0.20
9	MOD/SA (small)	25.9	1.80	0.02	1.62	0.02
10	MOD/SA (mid-size)	74.1	7.13	0.19	6.39	0.17
11	FBC/BB	678	2.06	0.51	1.85	0.46
12	FBC/CB	678	4.54	1.12	4.07	1.01
	TOTAL		66.64	14.95	63.81	14.48
Regulatory Alternative IIA						
1	MB/WW (small)	104	16.81	0.64	11.99	0.45
2	MB/WW (mid-size)	615	7.28	1.63	5.20	1.17
3	MB/WW (large)	1,730	8.49	5.36	6.06	3.82
4	MB/REF	384	3.24	0.45	2.31	0.32
5	MB/RC	807	3.24	0.95	2.31	0.68
6	RDF	1,500	5.39	2.95	2.98	1.63
7	RDF/CF	750	3.31	0.91	1.83	0.50
8	MOD/EA	178	3.35	0.22	3.49	0.23
9	MOD/SA (small)	25.9	1.80	0.02	1.87	0.02
10	MOD/SA (mid-size)	74.1	7.13	0.19	7.41	0.20
11	FBC/BB	678	2.06	0.51	2.15	0.53
12	FBC/CB	678	4.54	1.12	4.72	1.17
	TOTAL		66.64	14.95	52.32	10.72
Regulatory Alternative IIB						
1	MB/WW (small)	104	16.81	0.64	11.91	0.45
2	MB/WW (mid-size)	615	7.28	1.63	5.16	1.16
3	MB/WW (large)	1,730	8.49	5.36	6.02	3.80
4	MB/REF	384	3.24	0.45	2.29	0.32
5	MB/RC	807	3.24	0.95	2.29	0.68
6	RDF	1,500	5.39	2.95	2.98	1.63
7	RDF/CF	750	3.31	0.91	1.83	0.50
8	MOD/EA	178	3.35	0.22	3.47	0.23
9	MOD/SA (small)	25.9	1.80	0.02	1.86	0.02
10	MOD/SA (mid-size)	74.1·	7.13	0.19	7.37	0.20
11	FBC/BB	678	2.06	0.51	2.14	0.53
12	FBC/CB	678	4.54	1.12	4.70	1.16
	TOTAL		66.64	14.95	52.03	10.67

CONTINUED

TABLE 5-8. NSPSs MODEL PLANT NATIONAL WASTE FLOWS AND SCALING FACTORS [a,b]

Model Plant Number	Model Plant Description	Model Plant Waste Flow (Mg/day)	Scenario I Scaling Factor	Scenario I Total Waste Flows (10^6 Mg/yr)	Scenario III Scaling Factor	Scenario III Total Waste Flows (10^6 Mg/yr)
Regulatory Alternative III						
1	MB/WW (small)	104	16.81	0.64	10.54	0.40
2	MB/WW (mid-size)	615	7.28	1.63	4.57	1.02
3	MB/WW (large)	1,730	8.49	5.36	5.33	3.36
4	MB/REF	384	3.24	0.45	2.03	0.28
5	MB/RC	807	3.24	0.95	2.03	0.60
6	RDF	1,500	5.39	2.95	2.48	1.36
7	RDF/CF	750	3.31	0.91	1.52	0.42
8	MOD/EA	178	3.35	0.22	3.68	0.24
9	MOD/SA (small)	25.9	1.80	0.02	1.98	0.02
10	MOD/SA (mid-size)	74.1	7.13	0.19	7.82	0.21
11	FBC/BB	678	2.06	0.51	2.26	0.56
12	FBC/CB	678	4.54	1.12	4.98	1.23
	TOTAL		66.64	14.95	49.22	9.70
Regulatory Alternative IV						
1	MB/WW (small)	104	16.81	0.64	10.46	0.40
2	MB/WW (mid-size)	615	7.28	1.63	4.53	1.02
3	MB/WW (large)	1730	8.49	5.36	5.29	3.34
4	MB/REF	384	3.24	0.45	2.01	0.28
5	MB/RC	807	3.24	0.95	2.01	0.59
6	RDF	1500	5.39	2.95	2.47	1.35
7	RDF/CF	750	3.31	0.91	1.52	0.42
8	MOD/EA	178	3.35	0.22	3.66	0.24
9	MOD/SA (small)	25.9	1.80	0.02	1.97	0.02
10	MOD/SA (mid-size)	74.1	7.13	0.19	7.78	0.21
11	FBC/BB	678	2.06	0.51	2.25	0.56
12	FBC/CB	678	4.54	1.12	4.96	1.23
	TOTAL		66.64	14.95	48.93	9.65

[a] These scaling factors are based on the annual operating hours reported in Table 3-3. For 9 of the model plants these hours reflect the average capacity utilization, by plant type, reported in the *1988-89 Resource Recovery Yearbook* (Gould, 1988). Allowance is made for increased downtime for model plants 1 and 9; and allowance is also made for model plant 7 which co-fires 50 percent wood.

[b] These scaling factors are used to estimate the number of MWC plants subject to NSPSs.

CHAPTER 6
COST AND PRICE IMPACTS

This chapter presents the estimated costs of each regulatory alternative and scenario for each of the model plants and for the nation as a whole. These costs are based on engineering control cost estimates for 12 model plants that represent those plants affected by the NSPSs (EPA, 1989c). The national cost estimates are computed from both an enterprise and a social perspective.

6.1 MODEL PLANTS AND THE COST OF REGULATORY ALTERNATIVES

Table 6-1 lists the estimated additional capital and annual operating costs required by the 12 model plants to meet the emissions limits of each regulatory alternative. Also presented are the associated present value of costs, annualized costs, and costs per Mg of MSW. The cost data presented here are used directly to compute the cost of regulatory alternatives under Scenarios I and III. Costs are calculated based on two 15-year operating cycles for control equipment for all scenarios. This treatment assumes that the plant as a whole has an economic life of 30 years but that the APCD equipment has an economic life of 15 years. The operating costs are annual values based on the capacity utilization specified for the model plant. The operating costs include a credit for revenues when there is energy recovery during combustion. The present value of costs, the annualized costs, and the costs per Mg of MSW in Table 6-1 are based on public revenue bond financing of control expenditures by a public entity. The basis for the associated discounting and annualization procedures is discussed in Chapter 3. Costs in the table are zero when the model plant is small enough to qualify for exemption from emission limits or was originally designed to meet these limits.

In looking at these costs, note again that, while values reported on these tables are internally consistent, they are not necessarily comparable to costs reported in other studies. The basis for computing costs per Mg of MSW, for example, varies greatly in the literature. Differences include different base year dollars, nominal vs. real dollar flows, conventions for treatment and timing of cost and revenue categories, and scope of the analysis. However, since costs used in this report have been computed consistently, decision makers can use them to represent the relative economic attractiveness of the model plants when making choices among plants and technologies. The only qualification, an important one, is the assumption that the cost and credit data for the model plants used in this impact analysis are representative of similar MWC plants.

TABLE 6-1. NSPSs ENTERPRISE COSTS OF CONTROL FOR PUBLICLY OWNED MODEL PLANTS (1987 $)[a]

Model Plant #	Model Plant Description	PV of Capital Cost[b] ($10³)	Annual Operating Cost[c] ($10³/yr)	PV of Total Control Cost[d] ($10³)	Total Annualized Cost[e] ($10³/yr)	Annualized Cost per Mg MSW[f] ($/Mg)
Regulatory Alternative I		(1)	(2)	(3)	(4)	(5)
1	MB/WW (small)	0	0	0	0	0
2	MB/WW (mid-size)	747	39.0	1,420	82.0	0.37
3	MB/WW (large)	2,100	114	4,070	236	0.37
4	MB/REF	964	50.0	1,830	106	0.75
5	MB/RC	840	35.2	1,450	84.0	0.28
6	RDF	1,930	109	3,810	220	0.40
7	RDF/CF	1,930	49.8	2,790	161	0.59
8	MOD/EA	0	0	0	0	0
9	MOD/SA (small)	827	72	2,070	120	12.70
10	MOD/SA (mid-size)	0	0	0	0	0
11	FBC/BB	0	0	0	0	0
12	FBC/CB	0	0	0	0	0
Regulatory Alternative IIA						
1	MB/WW (small)	0	0	0	0	0
2	MB/WW (mid-size)	5,240	1,260	27,000	1,560	6.97
3	MB/WW (large)	12,200	2,890	62,100	3,600	5.69
4	MB/REF	4,320	1,070	22,800	1,320	9.38
5	MB/RC	5,940	1,640	34,400	1,990	6.75
6	RDF	11,900	3,250	68,100	3,940	7.20
7	RDF/CF	11,900	1,290	34,300	1,980	7.25
8	MOD/EA	0	0	0	0	0
9	MOD/SA (small)	827	72	2,070	120	12.70
10	MOD/SA (mid-size)	0	0	0	0	0
11	FBC/BB	700	919	16,600	959	0
12	FBC/CB	700	1,520	27,000	1,560	0
Regulatory Alternative IIB						
1	MB/WW (small)	1,710	540	11,000	639	16.90
2	MB/WW (mid-size)	5,240	1,260	27,000	1,560	6.97
3	MB/WW (large)	12,200	2,890	62,100	3,590	5.69
4	MB/REF	4,320	1,070	22,800	1,320	9.38
5	MB/RC	5,940	1,640	34,400	1,990	6.75
6	RDF	11,900	3,250	68,100	3,940	7.20
7	RDF/CF	11,900	1,290	34,300	1,980	7.25
8	MOD/EA	1,960	460	9,910	573	8.83
9	MOD/SA (small)	2,180	322	7,750	448	47.40
10	MOD/SA (mid-size	1,960	347	7,960	460	17.00
11	FBC/BB	700	919	16,600	959	3.88
12	FBC/CB	700	1,520	27,000	1,560	6.30

CONTINUED

TABLE 6-1. NSPSs ENTERPRISE COSTS OF CONTROL FOR PUBLICLY OWNED MODEL PLANTS (1987 $)[a] (CONTINUED)

Model Plant #	Model Plant Description	PV of Capital Cost[b] ($10³)	Annual Operating Cost[c] ($10³/yr)	PV of Total Control Cost[d] ($10³/yr)	Total Annualized Cost[e] ($10³/yr)	Annualized Cost per Mg MSW[f] ($/Mg)
Regulatory Alternative III		(1)	(2)	(3)	(4)	(5)
1	MB/WW (small)	0	0	0	0	0
2	MB/WW (mid-size)	8,870	1,450	38,900	2,250	10.00
3	MB/WW (large)	18,300	3,260	84,900	4,910	7.78
4	MB/REF	8,820	1,310	36,400	2,100	15.00
5	MB/RC	11,500	1,900	50,800	2,940	9.97
6	RDF	19,700	3,630	93,400	5,400	9.86
7	RDF/CF	19,700	1,480	56,100	3,240	11.90
8	MOD/EA	0	0	0	0	0
9	MOD/SA (small)	532	72	2,070	120	12.69
10	MOD/SA (mid-size	0	0	0	0	0
11	FBC/BB	8,560	1,340	36,500	2,110	8.54
12	FBC/CB	8,560	1,340	36,500	2,110	8.54
Regulatory Alternative IV						
1	MB/WW (small)	1,100	540	11,000	639	16.90
2	MB/WW (mid-size)	8,870	1,450	38,900	2,250	10.00
3	MB/WW (large)	18,300	3,260	84,900	4,910	7.78
4	MB/REF	8,820	1,310	36,400	2,100	15.00
5	MB/RC	11,500	1,900	50,800	2,940	9.97
6	RDF	19,700	3,630	93,400	5,400	9.86
7	RDF/CF	19,700	1,480	56,100	3,240	11.90
8	MOD/EA	1,260	460	9,910	573	8.83
9	MOD/SA (small)	1,400	322	7,750	448	47.40
10	MOD/SA (mid-size	1,260	347	7,960	460	17.00
11	FBC/BB	8,560	1,340	36,500	2,110	8.54
12	FBC/CB	8,560	1,340	36,500	2,110	8.54

[a] Control costs are costs over the baseline model plant costs of Chapter 3. These costs are incurred to meet the emission requirements of the NSPSs.

[b] Present value of capital costs of control are based on two consecutive 15-year life cycles for APCD equipment over the 30-year plant life.

[c] Annual operating costs are assumed to be constant from year to year.

[d] Present value based on 30-year operating life and 4 percent real rate of discount applied to column (2) and added to column (1). The NPV equation for publicly operated facilities is given in Chapter 3.

[e] Total annualized cost is based on addition of column (2) with annualization of column (1) over 30 years at 4 percent.

[f] Computed by dividing column (4) by the estimated amount of MSW processed per year at the model plant.

When choices arise, decision makers will be guided by the cost of choices as *they* see them. These are termed private or business enterprise costs even if a public entity is doing the accounting. As discussed in Chapter 3, this viewpoint will differ slightly for private and public entities' decision makers given their different financial environments—particularly their tax liabilities and opportunity costs of capital. Using the same cash flow model and financial parameters as in Chapter 3, the present value and per-Mg cost are computed for public and private plants. To illustrate how decision makers with different perspectives evaluate the control costs, Table 6-2 provides results for public and private financial environments for Regulatory Alternative IV.

The data of Table 6-2 show how an average private firm would view the two measures of the cost of control, after allowance for tax effects, of passing the full cost along to the customer, for the different model plants. Similarly, the data show how an average public entity would view the cost of control for different model plants given the public entities' cost of capital and lack of tax obligation. These measures provide a good basis for a single entity to compare different investment choices having the same revenue effects or meeting the same regulatory requirement. For example, the NPV measure can be the basis for a private firm's choice between building a new MWC (with an associated NPV or cost per Mg) or modifying a current MWC at the cost shown in Table 6-2.

The data of Table 6-2 also allow one to compare the cost of control between privately owned and publicly owned MWCs. Such comparisons, however, should be made with care because these entities have very different financial conditions. The NPV of total control costs are lower for private ownership for all model plants but the relative difference between public and private ownership varies from one model plant to another. These variations arise from a combination of differences in the cost of capital and tax obligations for privately owned and publicly owned MWCs and differences from one model plant to another in the share of capital and operating costs for APCD equipment.

The annualized costs per Mg of MSW, however, show that the average publicly owned MWC, with its financial conditions, would be able to meet the regulations at a lower cost (tipping fee increase), than a privately owned MWC in any model plant category. This measure is equivalent to asking, "What must the public entity or private firm receive per unit of waste disposed if it is to cover the costs experienced when investing in the pollution control equipment?" For the range of model plant capital and operating costs of control considered here, the cost of control per Mg of MSW ranges from 12 to 43 percent higher for private ownership

TABLE 6-2. NSPSs ENTERPRISE COSTS OF CONTROL FOR PUBLICLY AND PRIVATELY OWNED MODEL PLANTS: SCENARIO I, REGULATORY ALTERNATIVE IV[a]

Model Plant #	Model Plant Description	Capital Cost ($10³)	Operating Cost ($10³/yr)	Public: PV of Total Control Cost[c,e] ($10³/yr)	Public: Annualized Cost per Mg/MSW[c,e] ($/Mg)	Private: PV of Total Control Cost[d,e] ($10³/yr)	Private: Annualized Cost per Mg/MSW[d,e] ($/Mg)
		(1)	(2)	(3)	(4)	(5)	(6)
1	MB/WW (small)	1100	540	11,000	16.90	8,100	19.00
2	MB/WW (mid-size)	8,870	1,450	38,900	10.00	32,600	12.90
3	MB/WW (large)	18,300	3,260	84,900	7.78	70,300	9.89
4	MB/REF	8,820	1,310	36,400	15.00	30,900	19.60
5	MB/RC	11,500	1,900	50,800	9.97	42,500	12.80
6	RDF	19,700	3,630	93,400	9.86	76,900	12.50
7	RDF/CF	19,700	1,480	56,100	11.90	52,600	17.10
8	MOD/EA	1,260	460	9,910	8.83	7,490	10.20
9	MOD/SA (small)	1,400	322	7,750	47.40	6,190	58.20
10	MOD/SA (mid-size)	1,260	347	7,960	17.00	6,220	20.40
11	FBC/BB	8,560	1,340	36,500	8.54	30,800	11.10
12	FBC/CB	8,560	1,340	36,500	8.54	30,800	11.10

[a]Differences in annualized operating costs for privately and publicly owned facilities are due to differences in the cash flow models for these firms of ownership as well as differences in cash flow model parameters, especially the discount rate. See Chapter 3 for a discussion of these differences.

[b]Capital costs presented here are for one APCD equipment cycle only.

[c]Based on 4 percent discount rate, 2 consecutive, 15-year APCD equipment cycles, 30-year plant life, and the cash flow model for public financing and ownership.

[d]Based on 8 percent discount rate, 2 consecutive, 15-year APCD equipment cycles, 30-year plant life, and the cash flow model for private financing and ownership.

[e]The NPV of total control costs and the annualized costs are estimates of the revenue required, in present value and annualized terms, respectively, by the public and private entities if tipping fees are to cover all of the cost.

than for public ownership (the average difference is 25 percent). As in the case of NPV values, variations in the percentage differences in per-Mg MSW cost are due in part to the relative mix of capital and operating cost—as the capital cost increases relative to operating cost, the per-Mg cost differences shift in favor of public ownership.

These data suggest that, in situations where public and private entities compete to provide disposal of MSW by combustion, imposing the NSPSs would substantially favor public ownership. As noted above, this result *must* be interpreted with caution for the following reasons. First, it doesn't reflect any differences in the productivity that may exist for public and private owners of MWC plants. For example, private owners may be more efficient in installing and operating controls by virtue of multiple project experience. Second, the measured differences are also the product of the average financial parameters used to represent public and private ownership. The differences in per-Mg cost of MSW between public and private ownership are not so large that they are outside the range in variation associated with financial parameters of public entities and private firms. For example, Hilgendorff (1989) notes the backlog of MWC projects that qualify for the more favorable pre-1986 Tax Reform Act tax treatment under "grandfather" provisions of the Act. Even so, these cost-per-Mg data appear to corroborate the contention that, in the future, publicly owned MWC facilities will continue to be the norm.[1] The costs of meeting the NSPSs probably amplify the public ownership advantage in most cases.

Because of this finding and the already prominent role of public ownership of current MWC plants, cost impacts of the NSPSs are presented in the next two sections of this report using the cash flow model for public financing of control equipment. A discussion of social cost impacts follows later in this chapter.

Table 6-3 presents estimates of baseline costs per Mg MSW estimated for the model plants (based on capital and operating costs of the model plant prior to the NSPSs) and the per-Mg MSW cost for each regulatory alternative wherein the per-Mg MSW cost of APCD capital equipment and operation are added to the baseline costs per Mg of MSW. These data provide measures of the size of the costs of regulatory alternatives for each model plant relative to both the baseline cost and other regulatory alternatives. These same relative costs apply to Scenario III, only for fewer plants.

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[1]Hilgendorff (1989) notes the existence of a large number of planned plants that qualify as private participants for advantageous tax treatment under grandfather provisions of the 1986 Reform Act. For this group of plants, private firm accounting cost would be lower than portrayed in Table 6-2.

TABLE 6-3. NSPSs ENTERPRISE COSTS FOR PUBLICLY OWNED MODEL PLANTS[a] (1987$): SCENARIO I COST PER Mg OF MUNICIPAL SOLID WASTE AND PERCENTAGE CHANGES IN COST OVER THE BASELINE FOR EACH REGULATORY ALTERNATIVE

Model Plant #	Model Plant Description	Baseline Cost per Mg MSW[b] ($/Mg)	Regulatory Alt. I		Regulatory Alt. IIA		Regulatory Alt. IIB	
			Cost per Mg MSW[c] ($/Mg)	Percentage Change over Baseline	Cost per Mg MSW[c] ($/Mg)	Percentage Change over Baseline	Cost per Mg MSW[c] ($/Mg)	Percentage Change over Baseline
1	MB/WW (small)	75.40	75.40	0	75.40	0	92.30	22.4
2	MB/WW (mid-size)	20.70	21.10	1.77	27.70	33.7	27.70	33.7
3	MB/WW (large)	9.40	9.77	3.97	15.10	60.6	15.10	60.6
4	MB/REF	44.00	44.70	1.72	53.40	21.3	53.40	21.3
5	MB/RC	21.30	21.50	1.34	28.00	31.8	28.00	31.8
6	RDF	3.58	3.98	11.2	10.80	201.0	10.80	201.0
7	RDF/CF	17.70	18.30	3.33	25.00	40.9	25.00	40.9
8	MOD/EA	30.40	30.40	0	30.40	0	39.30	29.0
9	MOD/SA (small)	54.20	66.90	23.4	66.90	23.4	102.00	87.4
10	MOD/SA (mid-size)	31.20	31.20	0	31.20	0	48.30	54.5
11	FBC/BB	13.20	13.20	0	17.00	29.5	17.00	29.5
12	FBC/CB	13.20	13.20	0	19.50	47.9	19.50	48.0

CONTINUED

TABLE 6-3. NSPS ENTERPRISE COSTS FOR PUBLICLY OWNED MODEL PLANTS[a] (1987$): SCENARIO I COST PER Mg OF MUNICIPAL SOLID WASTE AND PERCENTAGE CHANGES IN COST OVER THE BASELINE FOR EACH REGULATORY ALTERNATIVE (CONTINUED)

			Regulatory Alt. III		Regulatory Alt. IV	
Model Plant #	Model Plant Description	Baseline Cost per Mg MSW[b] ($/Mg)	Cost per Mg MSW[c] ($/Mg)	Percentage Change over Baseline	Cost per Mg MSW[c] ($/Mg)	Percentage Change over Baseline
1	MB/WW (small)	75.40	75.40	0	92.30	22.4
2	MB/WW (mid-size)	20.70	30.70	48.5	30.70	48.5
3	MB/WW (large)	9.40	17.20	82.8	17.20	82.8
4	MB/REF	44.00	59.00	34.1	59.00	34.1
5	MB/RC	21.30	31.20	46.9	31.20	46.9
6	RDF	3.58	13.40	275.0	13.40	275.0
7	RDF/CF	17.70	29.60	66.9	29.60	66.9
8	MOD/EA	30.40	30.40	0	39.30	29.0
9	MOD/SA (small)	54.20	66.90	23.4	102.00	87.4
10	MOD/SA (mid-size)	31.20	31.20	0	48.30	54.5
11	FBC/BB	13.20	21.70	64.9	21.70	64.9
12	FBC/CB	13.20	21.70	64.9	21.70	64.9

[a] Costs based on annualization of control costs over 30 years with a real discount rate of 4 percent.

[b] Baseline costs are computed from capital costs annualized over 30 years, with a real discount rate of 4 percent, plus operating costs.

[c] Costs for regulatory alternatives are baseline costs plus the cost of control relative to the baseline.

6.2 NATIONAL ENTERPRISE COSTS OF EACH REGULATORY ALTERNATIVE

Table 6-4 lists the national enterprise cost impacts estimated for each regulatory alternative under Scenarios I and III based on public ownership of all the plants and the aggregation method described in Chapter 5. The capital cost is the initial equipment and installation cost for APCDs plus the discounted cost of these expenditures for replacement in the 15th year of operation. Estimated annualized cost and costs per Mg of MSW use the cash flow model described in Chapter 3 and the accounting and amortization procedures of Section 6.1.

TABLE 6-4. NSPSs NATIONAL COST IMPACTS: ENTERPRISE COSTS FOR PUBLICLY OWNED MODEL PLANTS (1987 $)

Scenario and Regulatory Alternative	Present Value of Capital Costs ($\$10^6$)	Annualized Costs[a] ($\$10^6$/yr)	Annualized Costs per Mg MSW[b] (\$/Mg)
Scenario I			
Regulatory Alternative I	41.4	5.15	0.37
Regulatory Alternative IIA	285	89.6	6.45
Regulatory Alternative IIB	336	106	7.10
Regulatory Alternative III	800	128	9.23
Regulatory Alternative IV	852	145	9.69
Scenario III			
Regulatory Alternative I	46.2	5.02	0.37
Regulatory Alternative IIA	188	62.5	6.35
Regulatory Alternative IIB	232	75.8	7.11
Regulatory Alternative III	499	80.5	9.09
Regulatory Alternative IV	540	93.0	9.65

[a] Costs based on annualization of control costs over 30 years with a real discount rate of 4 percent.
[b] Computed by dividing total annualized cost by the estimated amount of MSW processed per year.

The capital cost estimates show that these regulations will require a substantial initial financial commitment on the part of affected MWCs and that the regulatory alternatives differ substantially in the financial commitment required. If roughly 70 plants will be affected, the average capital cost under Scenario I ranges from $0.44 million per plant for Regulatory Alternative I to $7.8 million per plant for Regulatory Alternative IV. The capital costs for Scenario III are lower than for Scenario I because fewer MWC are projected to be built due to the NSPSs. The capital cost reduction under the different regulatory alternatives ranges from 2.6 percent under Regulatory Alternative I to 37 percent under Regulatory Alternative IV. We note again, however, that for Scenario III we haven't included in these cost data either the total or incremental capital cost of new landfills that would be needed to manage the solid waste that, without the NSPSs, would have been managed by new MWCs.

Annualized costs cover operating costs and amortized capital for a 30-year period. For Scenario I they exceed $100 million per year for all Regulatory Alternatives more stringent than IIA. With their annual impacts, these regulatory alternatives qualify as major regulations under Executive Order 12291. Annualized costs for Scenario III range from $5 million to $93 million per year. Again, costs for landfills that substitute for some of the combustors due to the NSPSs are not included in these data.

Table 6-4 shows the estimated average annualized enterprise costs per Mg of solid waste combusted by plants that have to install APCDs under a given regulatory alternative. If the regulatory alternative does not require that a MWC plant incur costs to meet the regulation, then the plant's waste stream is not included in the denominator used to compute cost per Mg. These data are discussed further below.

6.3 PRICE IMPACTS

The NSPSs will increase the cost of operating most MWC plants. The amount of this cost that is passed on in the form of higher tipping fees (prices) to waste collectors and by collectors, in turn, to waste generators in the form of higher collection fees, is determined by the institutional and market conditions prevailing in the MSW service area. In this section of the report we discuss several variations in institutional and market conditions that result in very different "price" impacts. In each instance we use enterprise costs to estimate these impacts because these are the costs estimated for the individual firm or government entity.

In circumstances in which different disposal technologies compete with one another without institutional constraints, the price of waste disposal will be established by the least-cost disposal option. For a privately owned plant, the plant would only be built if combustion was still the least-cost way to provide waste disposal services after the NSPSs and if the costs could be fully passed on to waste collectors. Thus for privately owned plants in a competitive market either all control cost are passed to consumers in the form of a price or tipping fee increase or the plant is not built and no costs of control for MWC plants are passed on. Most of this increase in tipping fees will, in turn, be passed on to waste generators if there is a highly inelastic demand for waste collection (as postulated in Chapter 2); that is, all collectors experience the same increase in tipping fees and the supply of waste collection is relatively elastic. In such a case, the price increases would, on average, be roughly equal to the cost-per-Mg values of Table 6-4.

For a publicly owned MWC plant, whether the MWC plant will be built and how the control costs will be allocated to price is a public policy decision. Notwithstanding the limits placed on it by the terms of any revenue bond financing arrangements, a public entity often has the option of covering some or all of the costs of combustion using tax revenue or fees derived from other services. If combustion is not the least-cost disposal alternative after the NSPSs, the price of the least-cost competing disposal technologies will probably set an upper bound on the extent to which NSPSs control costs can be passed along in the form of price increases. If combustion is the least cost solid waste disposal alternative, then the public entity may pass all or part of the cost of control along in the form of a price increase. Recall again, however, that because a public entity does not necessarily have to cover costs incurred in provision of a particular line of business, prices and costs are not necessarily linked closely with one another.

Price impacts will also vary because of the differences in costs of control for different MWC plants. Table 6-1 shows the range in control cost per Mg from model plant to model plant. For any given regulatory alternative, the individual model plant can have control costs from zero to many hundreds of percent above the average cost per Mg.

To provide some perspective on potential price increases, we compare the costs per Mg with average tipping fees reported for resource recovery facilities by Pettit (1989). The average tipping fee for resource recovery facilities in 1988 was $42.70 per Mg (1987 dollars). Pettit notes these important features of that figure:

- It is based on "gate fees" (municipality and/or contract waste may be charged lower tipping fees).
- Those facilities that reported zero tipping fees were excluded from the average.

Furthermore, Pettit notes that the average tipping fee has risen sharply over the past 7 years—68 percent since the average was first computed for 1982. This dramatic increase is likely due to some combination of both the introduction of new, more costly plants into the sample and a change in the pricing policies of owners and operators.

Table 6-5 provides the average percentage increases in tipping fees for scenario and regulatory alternative combinations, assuming that all the estimated increase in enterprise cost per Mg of MSW is passed through to the waste collector. The average percentage increase in tipping fees per Mg increases with the regulatory alternative and is significant beyond Regulatory Alternative I. The percentage increases for individual model plants vary considerably with both the model plant and regulatory alternative. This can also be seen by reviewing Table 6-3. There is wide variation in the percentage increases in cost per Mg associated with each regulatory alternative. Admittedly, much of this variation is due to the variations in the baseline cost per Mg used, but enough is attributable to the control cost itself to indicate that the price impacts of the NSPSs will vary widely depending on the size and technology of the MWC plants.

TABLE 6-5. PERCENTAGE PRICE INCREASES BASED ON FULL PASS THROUGH OF ESTIMATED NSPSs ENTERPRISE COSTS OF CONTROL PER Mg OF MUNICIPAL SOLID WASTE[a]

Scenario	Regulatory Alternative I	Regulatory Alternative IIA	Regulatory Alternative IIB	Regulatory Alternative III	Regulatory Alternative IV
Scenario I	0.86	15	17	22	23
Scenario III	0.86	15	17	21	23

[a] Based on average resource recovery facility tipping fee for 1988 of $43.96 per Mg (Pettit, 1989), converted to last quarter 1987$ to an average $42.70 per Mg.

In situations where there is little competition among waste disposal technologies or waste disposal firms, attempts to translate cost changes into price changes become even more problematic. Usually, disposal of solid waste in such non-competitive situations rests with a public entity. In this case the price increase will more than ever depend on how the public entity allocates costs.

6.4 SOCIAL COSTS

To calculate the social cost of a regulation, we recast the private cost data and insert them into a social opportunity cost framework. While, in principle, a multiplicity of issues account for differences between private and social costs, these issues usually center on selecting an appropriate discount rate and measuring social losses due to quantity adjustments.

Over the past several decades, views have ranged widely regarding the appropriate discount rate to use when evaluating a public project or estimating the economic impact of a government program. A recent discussion of the issues involved is presented in Lind (1982). While no particular approach commands the complete support of economists, a number of prominent economists agree that a recently introduced set of principles for discounting when seeking social measures of costs or benefits is a step in the right direction. This position is represented in two recent papers (Kolb and Scheraga, 1988; Arnold, 1986). In summary, these papers direct the analyst to employ a "two stage" or two discount rate procedure. A capital rate of discount is used to annualize any capital expense, and a consumption rate of interest (discount) is used to determine the present value of the annual expenditures, as well as the annualized capital cost. This procedure is used to estimate national social costs in this chapter. Because the procedure and the discount rates employed are still controversial, Chapter 9 includes results using single discount rates of 10 and 3 percent.

The papers provide only modest guidance on choosing the appropriate rates of consumption and capital discount. The general consensus is that the consumption rate of interest is lower than the capital discount rate. The consumption rate of interest has been estimated by various authors to be in the 0 to 6 percent range; the capital discount rate in the 8 to 13 percent range. This analysis uses a consumption rate of interest of 3 percent and a capital discount rate of 10 percent. The resulting social cost estimates for each scenario and regulatory alternative are shown in Table 6-6.

Because of the discounting procedure, the annualized and per-Mg social costs are 10 to 20 percent higher than comparable enterprise costs. The annualized cost of Regulatory Alternative IIA under Scenario I is now nearly $100 million and Regulatory Alternative IV under Scenario III is a "major" regulation using national social costs.

TABLE 6-6. NSPSs NATIONAL COST IMPACTS (1987 $)

Scenario and Regulatory Alternative	PV of Social Capital Costs ($10^6)[a]	Annualized Social Costs[b] ($10^6/yr)	Annualized Social Costs per Mg MSW[b,d] ($/Mg)	Annualized Enterprise Costs per Mg MSW[c,d] ($/Mg)
Scenario I				
Regulatory Alternative I	37.8	6.41	0.46	0.37
Regulatory Alternative IIA	227	97.2	6.99	6.45
Regulatory Alternative IIB	268	115	7.70	7.10
Regulatory Alternative III	638	150	10.80	9.23
Regulatory Alternative IV	676	168	11.20	9.69
Scenario III				
Regulatory Alternative I	36.9	6.26	0.46	0.37
Regulatory Alternative IIA	150	67.6	6.86	6.35
Regulatory Alternative IIB	185	82.0	7.69	7.11
Regulatory Alternative III	398	93.8	10.60	9.09
Regulatory Alternative IV	430	107	11.10	9.65

[a] Present value of capital costs are based on 2 consecutive, 15-year life cycles for APCD equipment over the 30-year plant life. These assumptions make no difference in the annualized cost impacts (Robson, 1989).

[b] Annualized social costs are the sum of capital costs, annualized at *10 percent*, and annual operating costs.

[c] Annualized public enterprise costs are the sum of capital costs, annualized at *4 percent*, and annual operating costs.

[d] Computed by dividing total annualized cost by the estimated amount of MSW processed per year.

CHAPTER 7
EMISSION REDUCTIONS AND COST-EFFECTIVENESS

MWC air emissions are changed, usually reduced, with the increased costs MWCs incur with the application of air pollution control devices (APCDs). For Scenario I the emission reductions are computed as the difference between estimates of baseline emissions from MWC plants and estimates of emissions after the installation of the APCDs on those plants. Emission reductions for Scenario III are computed differently because, as the controls called for by the NSPSs become more costly, fewer new MWC plants are built. The emission reductions for Scenario III computed in this chapter are the difference between baseline emissions from MWCs that will be built, which will be fewer than planned, and emissions from the same plants after the NSPSs. Two alternative ways of computing emission reductions for Scenario III are to compute them relative to the Scenario I baseline (in which case they would be larger than reported here) or, for a more comprehensive perspective, to compute them relative to the Scenario I baseline but to add back in emissions from landfills that substitute for the new MWC plants in Scenario III.

This chapter provides estimates of these reductions for six air emissions and solid waste, describes how they might be combined with cost data to obtain cost-effectiveness estimates, and notes the problems in comparing the cost-effectiveness of regulatory alternatives when emissions are denominated in different units (e.g., Mg of SO_2 vs Mg of HCl).

Scenario I energy impacts are also presented in this chapter. Energy impacts are computed as the difference between estimated baseline energy usage and energy usage after the regulation. Electrical energy usage is generally higher after the installation of APCD equipment. No change in gas usage is projected for any of the regulatory alternatives.

7.1 EMISSION REDUCTIONS AND ENERGY IMPACTS

Radian (EPA, 1989c) estimated emission reductions and energy impacts associated with use of APCDs for each model plant. APCDs control several pollutants both in the baseline and under the regulatory alternatives, including

- polychlorinated dibenzo-*p*-dioxins and dibenzofurans (CDD/CDF),
- carbon monoxide (CO),
- particulate matter (PM),
- hydrogen chloride (HCl),
- sulfur dioxide (SO_2),
- lead (Pb), and
- ash.

Table 7-1 presents estimated changes in national emissions for each pollutant associated with each of the regulatory alternatives under Scenarios I and III. Table 7-2 presents energy usage impacts associated with each of the regulatory alternatives under Scenario I. We compute these data using the same strategy of scaling model plant emissions, emission reductions, and energy impacts to national emissions, emission reductions, and energy impacts as that employed in estimating the national costs for these regulatory alternatives.

TABLE 7-1. NSPSs NATIONAL BASELINE EMISSIONS AND EMISSIONS REDUCTIONS (Mg per Yr.)

Scenarios and Regulatory Alternatives	CDD/CDF	CO	PM	SO_2	HCl	Pb	Ash[b]
Scenario I							
Baseline Emissions	0.0152	5,470	7,540	42,000	49,300	127	3,700,000
Emissions Reductions							
Regulatory Alternative I	0	0	5,220	0	0	88.5	-154,000
Regulatory Alternative IIA	0.0107	0	5,220	18,300	36,700	108	-383,000
Regulatory Alternative IIB	0.0115	0	5,960	19,300	39,500	124	-401,000
Regulatory Alternative III	0.0139	0	5,220	35,400	44,400	108	-314,000
Regulatory Alternative IV	0.0146	0	5,960	36,400	47,200	124	-332,000
Scenario III							
Baseline Emissions[a]	—	—	—	—	—	—	—
Emissions Reductions							
Regulatory Alternative I	0	0	5,120	0	0	86.3	-138,000
Regulatory Alternative IIA	0.00781	0	3,440	13,700	25,700	77.9	-308,000
Regulatory Alternative IIB	0.00841	0	4,040	14,500	27,900	90.3	-322,000
Regulatory Alternative III	0.00916	0	2,980	22,400	27,700	68.6	-232,000
Regulatory Alternative IV	0.00974	0	3,550	23,100	29,900	81.6	-246,000

[a] Scenario III baseline emissions vary with each regulatory alternative because the level of total waste flows handled by MWC varies with each regulatory alternative under Scenario III.

[b] Includes bottom ash and fly ash with some residual quench water. Negative values reflect increases in ash emissions relative to the baseline.

KEY: polychlorinated dibenzo-*p*-dioxins and dibenzofurans (CDD/CDF), carbon monoxide (CO), particulate matter (PM), sulfur dioxide (SO_2), hydrogen chloride (HCl), and lead (Pb).

TABLE 7-2. NSPSs NATIONAL ENERGY IMPACTS[a]

Scenario and Regulatory Alternative	Electrical Use (Tj/yr)	Gas Use (Tj/yr)
Scenario I		
Regulatory Alternative I	52.9	0
Regulatory Alternative IIA	501	0
Regulatory Alternative IIB	570	0
Regulatory Alternative III	687	0
Regulatory Alternative IV	755	0

[a] Energy impacts use refer to air pollution control only.

7.2 COST-EFFECTIVENESS

The cost-effectiveness of regulatory alternatives provides a measure of the cost per unit of emission reduction associated with each regulatory alternative. These ratios are meant to measure the marginal effectiveness of each regulatory alternative. So, first they must be arranged in order of increasing levels of emission reductions. Then, both the numerator and denominator of the cost-effectiveness ratio are calculated as the difference between costs (or emissions) of the regulatory alternative being evaluated and the previously most stringent alternative. To highlight the nature of the resulting cost-effectiveness ratios, some analysts refer to them as "incremental" cost-effectiveness measures. In mathematical terms, the cost-effectiveness ratio for regulatory alternative i and emission j is

$$CE_{ij} = (C_i - C_{i-1})/(E_{i-1j} - E_{ij}) \quad (7.1)$$

where C is cost and E is emissions.

This relationship has a number of other notable features. First, the presumption is made that costs increase and emissions decrease as the regulatory alternatives become more stringent. Thus, the level of costs under the next most stringent regulatory alternative is subtracted from the level of costs under the regulatory alternative of interest and vice versa for emissions. The cost-effectiveness measure, therefore, is positive under normal circumstances. The cost-effectiveness measure is the cost per unit of emission reduction for that regulatory alternative—for example, dollars per Mg of sulfur dioxide reduction.

Second, while this relationship can be applied to many different emissions, it has no inherent ability to identify which cost is assignable to which pollutant. To do this, either the regulatory alternatives must be redefined and narrowed to apply to only one emission of interest (all other emissions constant) or some way must be devised to find a common measure for valuing the emissions. Applying the cost-effectiveness measure to each of the pollutants when the APCDs are responsible for simultaneously controlling a number of pollutants, as in the case of MWCs, assigns all the cost for control to the particular pollutant for which the cost-effectiveness measure is computed. In this such circumstance, the cost-effectiveness measure overestimates the cost-effectiveness (i.e., implies emission reduction is more costly than in fact it is).

This obviously argues for a more comprehensive measure of cost-effectiveness—one that addresses the joint effectiveness of control on multiple emissions. Economists argue that such a comprehensive measure would be denominated in dollars, since the value of a commodity for purposes of trade is denominated in dollars. Put another way, if the additional benefit of a given emission reduction were measured in dollars, then the joint benefit of all emission reductions would be the sum of benefits of the individual emission reductions. Unfortunately, such benefit estimates are not available for many of the pollutants reduced by the NSPSs' regulatory alternatives. For this reason the cost-effectiveness estimates for individual pollutants are not presented at this time.

CHAPTER 8
ECONOMIC IMPACT ON SECTORS OF THE ECONOMY

The costs and emission reductions estimated for each of the regulatory alternatives will affect firms, households, and government units. This chapter examines in more detail how the costs associated with the regulatory alternatives will affect these sectors of the economy. In particular, we are interested in whether these costs are systematically larger for smaller entities or service areas and whether these impacts are severe under some of the criteria adopted in other analyses.

8.1 REGULATORY FLEXIBILITY ANALYSIS

The impact of government regulation on small entities (non-profit organizations, governmental jurisdictions, and businesses) is a special social concern as demonstrated by the Regulatory Flexibility Act of 1980. Among other things, the Act requires that federal agencies consider whether regulations they develop will have "a significant economic impact on a substantial number of small entities" (U.S. Small Business Administration, 1982).

Small government jurisdictions are identified in the Act as those with populations less than 50,000. Small businesses are identified by the Small Business Association general size standard definitions. These vary by Standard Industrial Classification (SIC) code. For SIC code 4953, Refuse Systems, small business concerns are those receiving less than $6 million dollars per year averaged over the most recent 3 fiscal years. These definitions are not, however, fixed for all regulatory actions. According to both SBA (1982) and EPA (1982) guidelines, with appropriate justification these definitions can be modified by the regulatory agency.

EPA (1982) provides guidelines for determining when a "substantial number" of these small entities have been "significantly impacted." Impacts may be considered significant if:

1. compliance costs are greater than five percent of production costs,
2. compliance costs, as a percent of sales, are at least 10 percent higher for small entities than for other entities,
3. capital costs of compliance are a significant portion of capital available, or
4. the requirements are likely to result in closures of small entities.

Three of these criteria apply absolute measures, but the second measure determines the adversity of the impact on small entities relative to other, larger entities. In its guidance, EPA also notes that these criteria, as well as the criterion suggested for determination of a "substantial number" are only guidelines, and that lead Offices may adopt other criteria as appropriate.

In its guidance EPA suggests that a "substantial number" is "more than 20 percent of these (small entities)...affected for each industry the proposed rule would cover." This criterion is open to a certain amount of interpretation as to the scope of the industry and "affected" industry segments. In this analysis we choose to address the question of "a substantial number" by treating public entities and private businesses separately. We assume that any entity that operates a MWC plant will be "affected," and determined that a "substantial number" of small entities are affected if small entities are more than nominally represented in the industry segment.

8.2 PRIVATE BUSINESS IMPACTS

Impacts of the regulation on private firms may be direct or indirect in nature. Owners who must purchase and install control equipment, train employees, or change operating practices will be directly impacted. On the other hand, firms that supply services or equipment but do not own a plant will be indirectly impacted, and may actually benefit from the regulation as demand for air pollution control technology and equipment increases. The extent of impacts for a specific MWC plant owner or supplier is dependent on local market conditions and contractual arrangements, size of the MWC plant, and financial status of the firm.

Many of the privately owned "merchant" MWC plants are large and were built (or are about to be built) under much more favorable tax and financing conditions than would likely apply to control equipment used to meet the NSPSs. Based on the cash flow analysis of Chapter 6, the NSPSs will result in higher control costs for private owners than for public owners of MWC plants. For private MWC plants that have long-term contracts to dispose of waste that include escalator provisions to cover contingencies such as pollution control equipment, these higher costs can be passed on to waste collectors and generators. Private MWC plants generally have such arrangements.

In contrast, privately owned plants that don't have such long-term contracts will be adversely affected by the NSPSs. How adverse the effect will be depends on the cost of production of the private MWC plant relative to other local means of solid waste disposal. If, after the NSPSs, the private plant still has relatively low costs of production, the NSPSs will reduce expected profits but will not force sale or closure of the plant. If, however, control costs are large enough to increase cost of production beyond prevailing tipping fees at landfills or public MWC plants, the private MWC plant may have to close or operate at a loss in the hope that tipping fees increase in the future. A local cost and market analysis for each such private MWC plant would be required to determine the severity of the NSPSs' impacts.

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In contrast, privately owned plants that don't have such long-term contracts will be adversely affected by the NSPSs. How adverse the effect will be depends on the cost of production of the private MWC plant relative to other local means of solid waste disposal. If, after the NSPSs, the private plant still has relatively low costs of production, the NSPSs will reduce expected profits but will not force sale or closure of the plant. If, however, control costs are large enough to increase cost of production beyond prevailing tipping fees at landfills or public MWC plants, the private MWC plant may have to close or operate at a loss in the hope that tipping fees increase in the future. A local cost and market analysis for each such private MWC plant would be required to determine the severity of the NSPSs' impacts.

Current information on significant events in the waste management industry highlight the rapidly changing market conditions for private firms. Several firms have been involved in recent mergers or acquisitions, including the following high-profile transactions:

- Wheelabrator Technologies, Inc. and its majority shareholder, The Wheelabrator Group, Inc. plan to merge and create a combined company Wheelabrator Technologies, Inc.(*Waste-to-Energy Report,* June 28, 1989, p.1).
- Environmental Systems Company (Ensco) acquired almost 1.7 million shares of Consumat, giving Ensco 54 percent ownership of Consumat (*Waste Age*, May 1989, p. 108).
- Bramble Industries, Ltd., an Australian firm, has the potential to convert $60 million in recently purchased Ensco securities into near-controlling interest in the company (*Waste Age*, May 1989, p. 110).
- Joy Technologies purchased Ecolaire for $1.5 million cash (*Waste Age*, May 1989, p. 114).
- Waste Management recently traded its combustor plants and a wastewater treatment plant to Wheelabrator for a 22 percent equity position in Wheelabrator (*Waste Age*, June 1989, pp. 74-75).

8.2.1. Private Owner Profile

Historical data were used to project impacts for plants subject to NSPSs. We assumed that the profile of plant ownership under the NSPSs could be projected using the information on owners of existing plants. We compiled a list of firms that own MWC plants using the *1988-89 Resource Recovery Yearbook* (Gould, 1988) and the data gathered under Section 114 of the CAA (EPA, 1988a). This list includes owners of plants currently in operation as well as owners of plants now in planning stages and plants under construction. We then obtained annual sales data on those firms included in *Moody's Industrial Manual* (1988), *Standard and Poors Register of Corporations*, business periodicals (*Fortune*, April, 1989; *Business Week*, Special Edition, 1989), and *Waste Age* (May, 1989 and June, 1989).

Telephone contacts were made with firms not included in these sources to obtain annual sales figures and to confirm information about the firm's line of business and organizational structure. It should be noted that financial data for many of the firms initially identified are unavailable due to difficulty contacting the firm, or reluctance on the part of the firm to release the information. In addition, this list does not necessarily represent a complete listing of private owners of MWCs since recent mergers, acquisitions, or plant closures may not be reflected in the data. Table 8-1 lists the firms we were able to identify as owners of MWC plants, their annual sales in millions of dollars, and a brief description of the firms' activities.

TABLE 8-1. MWC PRIVATE OWNER PROFILE

Firms	Annual Sales[a] ($$10^6$)	Line of Business (Other Than MWC Ownership)
General Motors Corp.	101,780	Auto, truck, bus, locomotive, aircraft manufacturer
Ford Motor Co.	92,446	Auto, truck, tractor & implement manufacturer
Occidental Chemical Corp.	19,417	Chemical manufacturer
Westinghouse	12,500	Electrical products, construction, financial services
Ford Motor Credit Corp.	5,850	Finance company
James River Corp.	5,623	Paper and disposable packaging manufacturer
Southern California Edison	5,490	Electric utilities services
General Electric Capital	3,600	Finance company
Waste Management	3,566	Recycling, medical wastes, chemical wastes
Combustion Engineering	3,484	Hazardous waste systems, consulting, mass transit engineering
Northern States Power (Elk River, MN)	1,770	Electric, gas, steam, telephone utilities
Wheelabrator	1,205	Environmental services & consulting
Ogden-Martin	1,088	Environmental engineering & design services,financial services
Foster Wheeler	1,054	Sludge processing, hazardous waste systems
Joy Technologies[b]	500	Air pollution control equipment
Blount Energy Resources	460	General contractor
Zurn Industries	406	Air pollution control equipment, energy recovery systems
Research-Cottrell	348	Air pollution control equipment, energy recovery systems
Katy-Seghers, Inc.	261	Oil field equipment, bearings
Dravo	248	Engineering and consulting services
Environmental Systems Co.	66.4	Hazardous waste management services
Reuter, Inc.	30.2	Plastic refuse container, recycling, composting
Consumat[b]	14.4	Modular systems manufacturer
KTI Energy, Inc.	>6	
Maine Energy Recovery Co. (MERC)	>6	
Penobscot Energy Recovery Co. (PERC)	>6	
Vicon Recovery Industries	1	
American Ref-Fuel	N/A	
Channel Sanitation Corp.	N/A	
Waste Resources Association	N/A	

Continued on next page

TABLE 8-1. MWC PRIVATE OWNER PROFILE (continued)

Firms for Which Financial Data Were Unavailable in Business Publications

American RR Inc.	Refuse Energy Systems Co.
Bridgeport RESCO Co.	Rhode Island SW Mgmt.
Camden Co. Energy Res. Assoc.	Richards Asphalt
Catalyst W-T-E Corp.	Savannah Energy Systems Co.
Channel Landfill, Inc.	SEMASS Partnership
Flour RR of Mass, Ltd. Prt.	SES Claremont Co. Ltd. Ptn.
Mass REFUSETECH Inc.	Signal Environmental Systems
New England Trust Company	Southland Exchange, Inc.
North County RR Corp.	St. John's University
Power Recovery Systems	Truckee Meadows Ltd. Ptn.
Pulaski Co. Ltd. Ptn.	Ukiah Energy Inc.
Quadrant	Waste Energy Partners Ltd. Prt.

[a]Annual sales given for the most recent year available.

[b]Estimated using 9-month total sales volume figures.

Sources: *Moody's Industrial Manual* (1988), *Standard and Poors Register of Corporations* (1989), *Fortune* (April 1989), *Business Week* (Special Edition 1989), and *Waste Age* (May 1989 and June 1989)

Approximately one-third of the firms we identified are publicly held corporations; the remaining majority are privately held firms including corporations and limited partnerships. Some are very large and diversified firms (e.g., General Motors Corporation). Although some firms for which financial data are not public would not disclose the actual amount of their annual sales when contacted by telephone, several did say that annual sales were substantially larger than the $6 million dollar cut-off specified by the Small Business Administration as the criterion for defining a small business in this industry. Only one firm was identified as having less than $6 million in annual sales, suggesting that small businesses are only nominally represented in the MWC segment of the industry. Therefore, under our analysis, a substantial number of small business are not significantly impacted. These data do suggest, however, great disparity in annual revenues between the smallest and the largest of these firms. Consequently, we examined the relationship between impacts, plant size, and firm size under these regulatory alternatives.

Table 8-2 shows the annualized costs per Mg under the most stringent regulatory alternative for privately owned model plants ordered by design capacity. Impacts are greater for small model plants than for large plants. Because of this indication of a relationship between the size of the plant and the severity of the impact, EPA has provided greater regulatory flexibility for small plants.

TABLE 8-2. NSPSs ENTERPRISE COSTS OF CONTROL FOR PRIVATELY OWNED MODEL PLANTS UNDER REGULATORY ALTERNATIVE IV: ORDERED BY DESIGN CAPACITY[a]

Model Plant #	Model Plant Description	Design Capacity (Mg/day)	Annualized Cost per Mg[b] ($/Mg)
9	MOD/SA (small)	45	58.20
10	MOD/SA (mid-size)	90	20.40
1	MB/WW (small)	180	19.00
8	MOD/EA	220	10.20
4	MB/REF	450	19.60
2	MB/WW (mid-size)	730	12.90
11	FBC/BB	820	11.10
12	FBC/CB	820	11.10
5	MB/RC	950	12.80
6	RDF	1,810	12.50
7	RDF/CF	1,810	17.10
3	MB/WW (large)	2,040	9.89

[a] Variations in annualized cost per Mg may also be due to effects other than capacity including energy recovery capabilities, MWC technology differences, and capacity utilization.

[b] Based on 8 percent discount rate, 15-year equipment life, and the cash flow model for private financing and ownership.

Specific measures to address the needs of small plants include: size cut-offs built into the regulatory structure and less stringent requirements for small plants. We have used costs for small plants to estimate impacts for smaller firms and costs for large plants to estimate impacts for larger firms. While there is no evidence to *clearly* indicate a relationship between the size of the plant and the size of the firm that owns the plant, if small firms do generally own small plants, the regulatory flexibility measures aimed at small plants will help mitigate these impacts.

8.2 2 Private Supplier Profile

Historical data were used to project the indirect impacts of NSPSs on private suppliers. We assumed that the profile of private suppliers could be projected using data for existing plants. To assess these indirect impacts, plant construction managers and technology suppliers were identified using information found in a *Kidder, Peabody Report* on resource recovery (April 29, 1988). Annual sales data were then obtained using the same sources previously used to obtain for financial data for private owners.

Table 8-3 identifies current market shares and projected capacity of firms currently acting as plant construction managers. Only 7 firms are identified as managers of projects due to come on line after 1991. Table 8-4 presents similar information for suppliers of services and equipment. Together, Martin, Von Roll, and Consumat supply over one-half of the plants included in this study. We don't expect to observe any adverse impacts on firms managing or supplying services and equipment to owners of new MWC plants; these firms will likely benefit from increased demand for their services. Therefore we conclude that a substantial number of small businesses will not be adversely affected by the proposed regulation.

8.3 IMPACTS ON HOUSEHOLDS AND GOVERNMENT ENTITIES

Analyzing the economic impacts of the NSPSs on households and government entities was difficult because of the uncertainty regarding community characteristics, special conditions relating to ownership, contractual arrangements, and financial responsibility, and variation in accounting practices among government entities. We introduced assumptions into our analysis that have the tendency to overestimate impacts, thereby assuring the credibility of any "no severe impacts" results. The assumptions we adopted to facilitate this "screening process" include:

1. assumptions that tend to underestimate the population of each service area, and
2. assumptions that tend to overestimate control costs.

TABLE 8-3. MWC SYSTEMS PRIVATE SUPPLIER PROFILE: PROJECT MANAGERS

Firm	Operating Capacity Through 1991[a]		Operating Capacity After 1991[a]	
	Mg/day	Percent	Mg/day	Percent
American Ref-Fuel	9,297	9.1%		
Babcock & Wilcox	3,628	3.5%		
Blount	2,095	2.0%		
Catalyst Energy	454	0.4%		
Combustion Engineering	7,936	7.8%	1,088	12.5%
Consumat	3,137	3.1%	934	10.7%
Dravo	2,376	2.3%		
Flour Daniel	707	0.7%		
Foster Wheeler	3,311	3.2%	544	6.2%
General Electric	1,204	1.2%		
Katy-Seghers	816	0.8%		
Morrison-Knudson	213	0.2%		
Ogden Martin	19,582	19.2%	3,129	35.9%
Pennsylvania Engineering	833	0.8%		
Riley Energy Systems	454	0.4%		
Vicon Recovery Systems	2,141	2.1%		
Waste Management	2,902	2.8%		
Westinghouse Electric	5,068	5.0%	884	10.2%
Wheelabrator Environmental	10,335	10.1%	1,361	15.6%
Miscellaneous	25,742	25.2%	771	8.8%
TOTAL	102,233	100.0%	8,712	100.0%

[a] Based on orders.

Source: McCoy, R.W., Jr., and R.J. Sweetnam, Jr. 1988. "A Status Report on Resource Recovery." *Kidder, Peabody Report.* April 29.

TABLE 8-4. MWC SYSTEMS PRIVATE SUPPLIER PROFILE: TECHNOLOGY SUPPLIER

Firm	Operating Capacity Through 1991[a]		Operating Capacity After 1991[a]	
	Mg/day	Percent	Mg/day	Percent
Babcock & Wilcox/Detriot Stoker	10,079	10.1%		
Combustion Engineering	8,344	8.3%		
Combustion Engineering/ Detriot Stoker	358	0.4%		
Consumat Systems	3,974	4.0%		
De Bartolomeis	680	0.7%		
Deutsche Babcock	9,297	9.3%		
Foster Wheeler/Detriot Stoker	5,451	5.5%		
Keeler/Dorr-Oliver/Detriot Stoker	671	0.7%		
Martin	25,643	25.7%	3,129	58.2%
Riley Stoker/Detriot Stoker	1,723	1.7%		
Seghers Engineers	816	0.8%		
Stienmuller	2,376	2.4%		
Vicon Recovery Systems	2,848	2.8%		
Volund	3,116	3.1%		
Von Roll	16,303	16.3%	1,361	25.3%
Westinghouse O'Conner	6,182	6.2%	884	16.5%
Widmer & Ernst	2,095	2.1%		
TOTAL	99,957	100.0%	5,374	100.0%

[a] Based on orders.

Source: McCoy, R.W., Jr., and R.J. Sweetnam, Jr. 1988. "A Status Report on Resource Recovery." *Kidder, Peabody Report* April 29.

The first step in computing geographically specific regulatory impacts is to identify the plants to be affected by the regulation. Radian (EPA, 1989c) presents a projected distribution of 138 plants to be affected by the NSPSs based in part on a list of plants in early planning stages, and in part on recently constructed or under-construction plants.[1] However, Radian's distribution of model plants identifies the plant capacity and the technology used for only 85 plants. It provides no information about the probable location of affected plants of each model plant type.

To assess the impacts of the NSPSs on households and government units, the affected plants must be associated with particular geographic locations. This assignment was made based on a profile of the relationship between capacity and service area for existing MWC plants. For each of the 85 affected plants, we compiled the following information:

- ownership,
- the technology used,
- the annual throughput,
- the model plant that represents the actual plant, and
- the geographic location.

Specific ownership information is available for existing plants from the Section 114 letters (EPA, 1988a) or from the *1988-89 Resource Recovery Yearbook* (Gould, 1988). These two sources, however, have no information for plants to be regulated under the NSPSs. We therefore made the assignment of ownership to NSPSs plants based on the ownership and throughput distribution of existing plants. Univariate statistics computed for existing plants indicate that privately owned plants tend on average to be somewhat larger than county-owned plants, which, in turn, are somewhat larger than municipally owned plants. We assigned ownership to projected plants so as to mimic, to the extent possible, the size distribution by ownership category that is observed for the existing plants. A frequency distribution of assigned plant ownership is shown in Table 8-5.

These same sources provide information on the areas served by existing plants. Again, however, they have no information about the plants to be covered by the NSPSs. They could serve only the community in which they are located, several communities, the entire county in which they are located, or several counties. Again, we assigned service areas so as to roughly mimic the service area distribution that is observed for the existing plants. After arranging the

[1] This projection does not conform to that used to estimate aggregate cost and emission reductions in Chapters 6 and 7. It does, however provide the basis for a technology and community profile used in this analysis.

TABLE 8-5. ESTIMATED OWNERSHIP OF NSPSs PLANTS[a]

Owner	Number of Plants	Percent of Plants
Private	36	41.9
County	16	19.7
Municipality	32	37.2
Federal	1	1.2
TOTAL	85	100

[a]Based on statistical relationship between the size of the plant and the type of ownership for existing MWC plants.

plants projected under our analysis by estimated throughput, we assigned the smallest 10 (11 percent) to the municipality category. For these plants, we used municipality data from the Census of Population and Housing to assess government and household impacts of the regulation. The remaining 75 plants were assumed to serve either the entire county in which they were located or a multi-city or multi-county area. For these plants, we used data from the Census of Population and Housing for only the county specified as the geographic location to compute their household impact indices.

Each plant was assigned one county as its service area unless it was specifically designated as serving "only one city." This procedure tends to underestimate the population base served in those cases where the actual service area includes multiple counties and/or multiple cities with total population greater than the designated county (see Assumption 1 above).[2] Since household and government impact indices use population data to calculate the financial base responsible for bearing the control costs imposed by the regulations, impacts may be overestimated.

To assess the impacts of the NSPSs on households and government entities, we first computed plant-specific costs of compliance. Costs of the various regulatory alternatives were assigned to actual plants based on the model plant designations of the industry profile (Radian, 1988a). When calculating control costs, we assumed that all plants are just meeting federal

[2]For those plants serving multiple cities with total population less than the designated county the population base would be overestimated. However, in the follow-up telephone contacts for government entities no MWC plant had a service area which included less than one county.

standards for emissions in the baseline (see Assumption 2 above). This assumption may tend to overestimate control costs for those plants with baseline controls that remove more pollution than called for by current federal standards. Using cost-of-compliance information for the model plants, we computed two measures of cost for each plant, under each of the five regulatory alternatives. These two costs are total annualized enterprise cost of compliance and total capital cost for both public and private forms of ownership. Total annualized enterprise cost of compliance for a plant equals the annual waste flow (Mg/yr) for the plant multiplied by the total annualized compliance cost per Mg for the appropriate model plant. To compute capital cost of compliance for a plant, capital cost of compliance for the first APCD equipment cycle of the appropriate model plant is scaled up or down based on the ratio of the plant's annual waste flow to the appropriate model plant's annual waste flow.

8.3.1 Household Impacts

All MWC plants, whatever their ownership, are likely to pass increased costs on to their customers. Among these are households, which generate much of the municipal waste incinerated annually. To assess the impacts of the NSPSs on households, 1980 Census of Population data were collected on each of the municipalities and counties in which plants are located. The data collected include the county population, number of households, median household income, and per capita income. The monetary values were inflated from 1980 dollars to fourth-quarter 1987 dollars using the GNP deflator (*1988 Economic Report of the President*, p. 252).

As previously described, the total annual compliance cost of the regulation was computed by multiplying enterprise cost per Mg times each plant's estimated throughput. We calculated different compliance costs for each model plant, depending on whether the plant is publicly or privately owned. For purposes of computing the plant-specific compliance costs, we used the cash flow model with private ownership for the privately owned plants, and the cash flow model with public ownership for all other plants. This may be somewhat inaccurate for authority-owned plants, which describe themselves as "quasi-public." In fact, their financing is probably much like that of a public plant. After computing total annual compliance costs for each plant, we summed the plant compliance costs over the plants within each service area to find the compliance cost incurred in each service area.

The inherent tendency toward underestimation of service area population has the effect of underestimating the population base responsible for financing the control costs of the plant or plants located in each service area. Consequently, the first step in the screening procedure was designed to compensate for this bias: only those service areas whose estimated waste generation roughly matched the capacity of the plant or plants located in that service area were included in the analysis. In particular, only the 23 service areas with implied capacity utilization between 40 percent and 400 percent for modular plants and 60 percent and 400 percent for all other plants were included. We combined census data associated with the 23 counties or municipalities with control cost data for the affected plants and used the data to estimate two service-area-specific household impact indices:

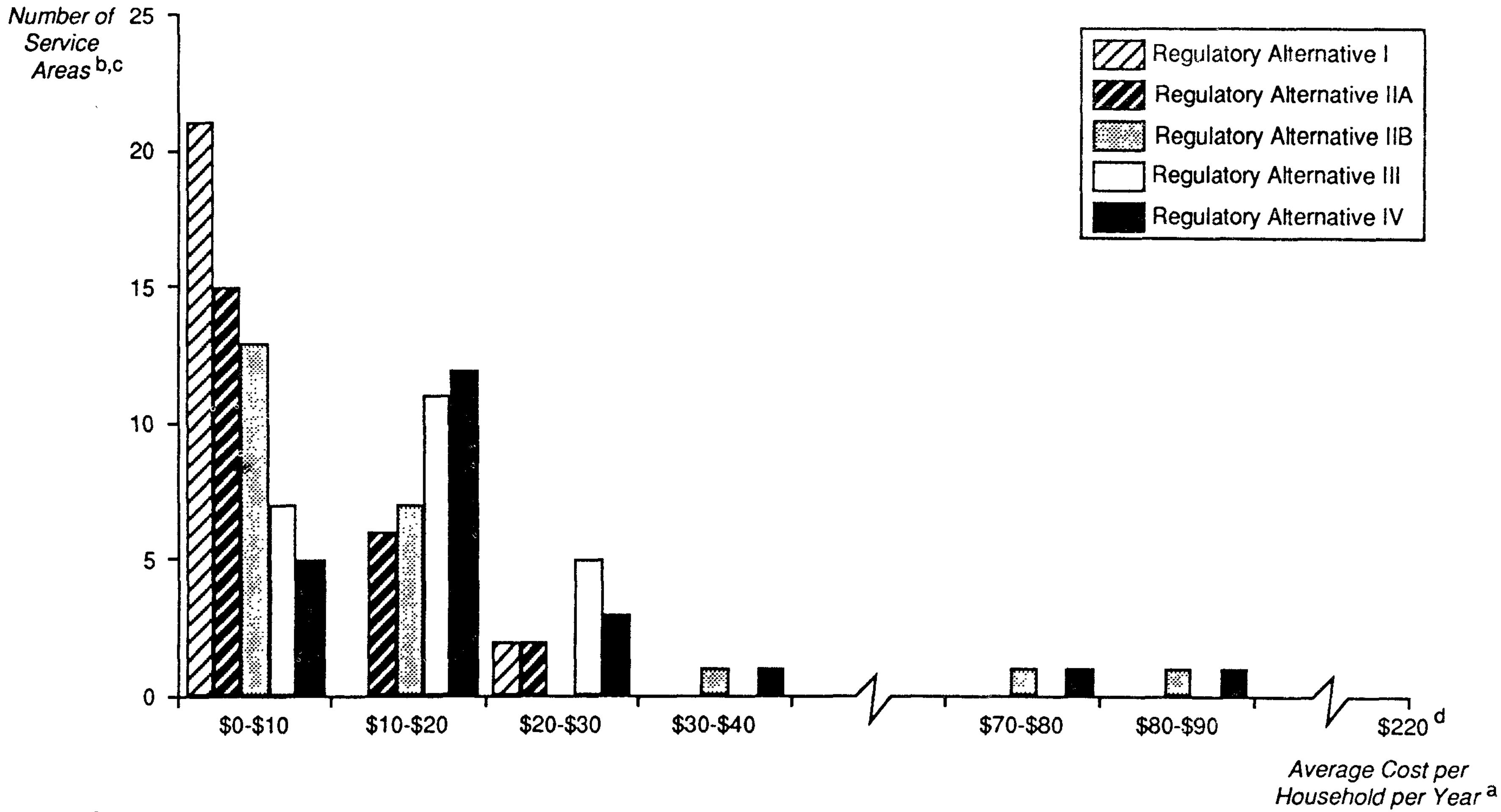
1. compliance cost per household, and
2. compliance cost per household as a percentage of median household income.

These indices had been used previously by EPA's Office of Solid Waste (OSW) in its Subtitle D Landfill Regulatory Impact Analysis (RIA) (Temple, Barker and Sloan et al., 1987). They are a rough measure of the household burden associated with the regulation: the former is an absolute dollar measure per household, while the latter is a measure of the cost of the regulation relative to the income of an average household. In the OSW Landfill RIA, a service area is defined as having severe household impacts if either:

1. compliance cost per household exceeds $220, or
2. compliance cost per household exceeds 1 percent of median household income.

Based on either criterion, none of the 23 service areas had severe household impacts under any of the regulatory alternatives. However, it should be noted that our sample does not include service areas with a population less than 2,500 because of census data limitations. Additionally, these results are based on conditions of national average waste generation per household and the assumption that all served households share equally in paying the cost of compliance. In practice, the impact of the regulation on individual households would depend on actual waste generated, actual household income, and the method by which individual jurisdictions pass on costs to their customers. While on average, impacts of compliance are not severe, there may well be special contractual or technical conditions, especially for small communities and service areas, where these costs, in combination with the costs of other environmental regulations, may impose unusual hardships.

Figures 8-1 and 8-2 show the distribution of household impacts measured by each index. Under the most stringent regulatory alternative, no service area averages control costs greater than $89 per household per year or 0.5 percent of median household income per household per year. Costs for 90 percent of all households average less than $30 per household per year in Figure 8-1 and less than 0.13 percent of median household income per household per year in



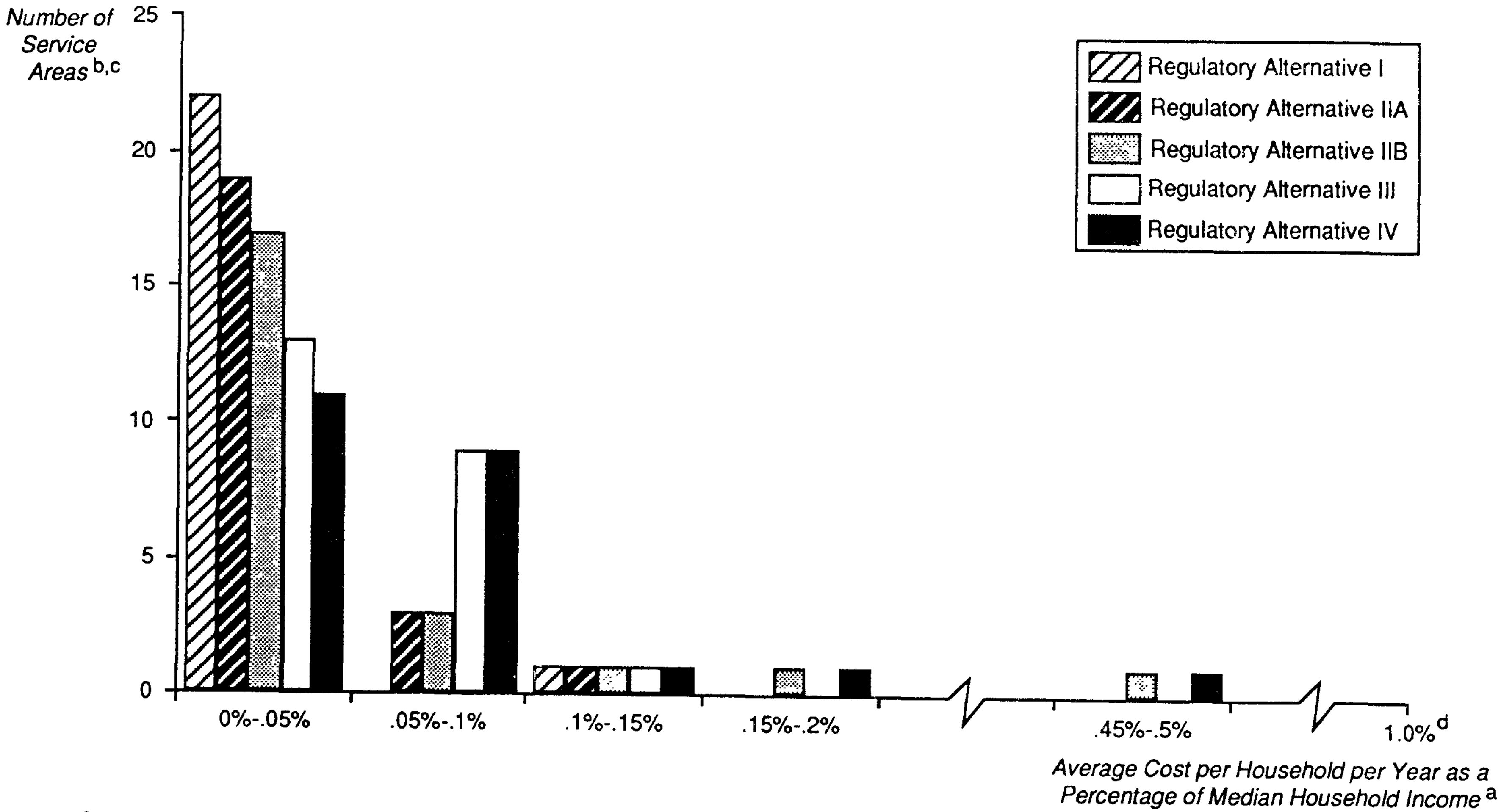
[a] Costs refer to control costs only; no baseline costs are included.

[b] Service areas with less than 2,500 total population were not included in the sample because census data for these service areas were not available.

[c] Service areas with implicit capacity utilization less than 40 percent for modular plants, less than 60 percent for other technologies, or greater than 400 percent for all technologies were not included in the sample. See text for discussion.

[d] Household impacts were defined as "severe" if average cost exceeds $220 per household per year.

Figure 8-1. Distribution of Household Impacts Under NSPSs by Number of Service Areas and Regulatory Alternative: Index 1



[a] Costs refer to control costs only; no baseline costs are included.

[b] Service areas with less than 2,500 total population were not included in the sample because census data for these service areas were not available.

[c] Service areas with implicit capacity utilization less than 40 percent for modular plants, less than 60 percent for other technologies, or greater than 400 percent for all technologies were not included in the sample. See text for discussion.

[d] Household impacts were defined as "severe" if average cost exceeds 1 percent of median household income per household per year.

Figure 8-2. Distribution of Household Impacts Under NSPSs by Number of Service Areas and Regulatory Alternative: Index 2

Figure 8-2. The average control cost per household per year is $20, translating to 0.08 percent of median household income per household per year.

In Figures 8-3 and 8-4 service areas are grouped in population size categories, and median impacts in each category are presented for the five regulatory alternatives. It appears that smaller service areas have slightly higher household impacts. In particular, greater control of smaller combustors under Regulatory Alternatives IIB and IV more than double the household impact for the smaller communities.

8.3.2 Governmental Impacts

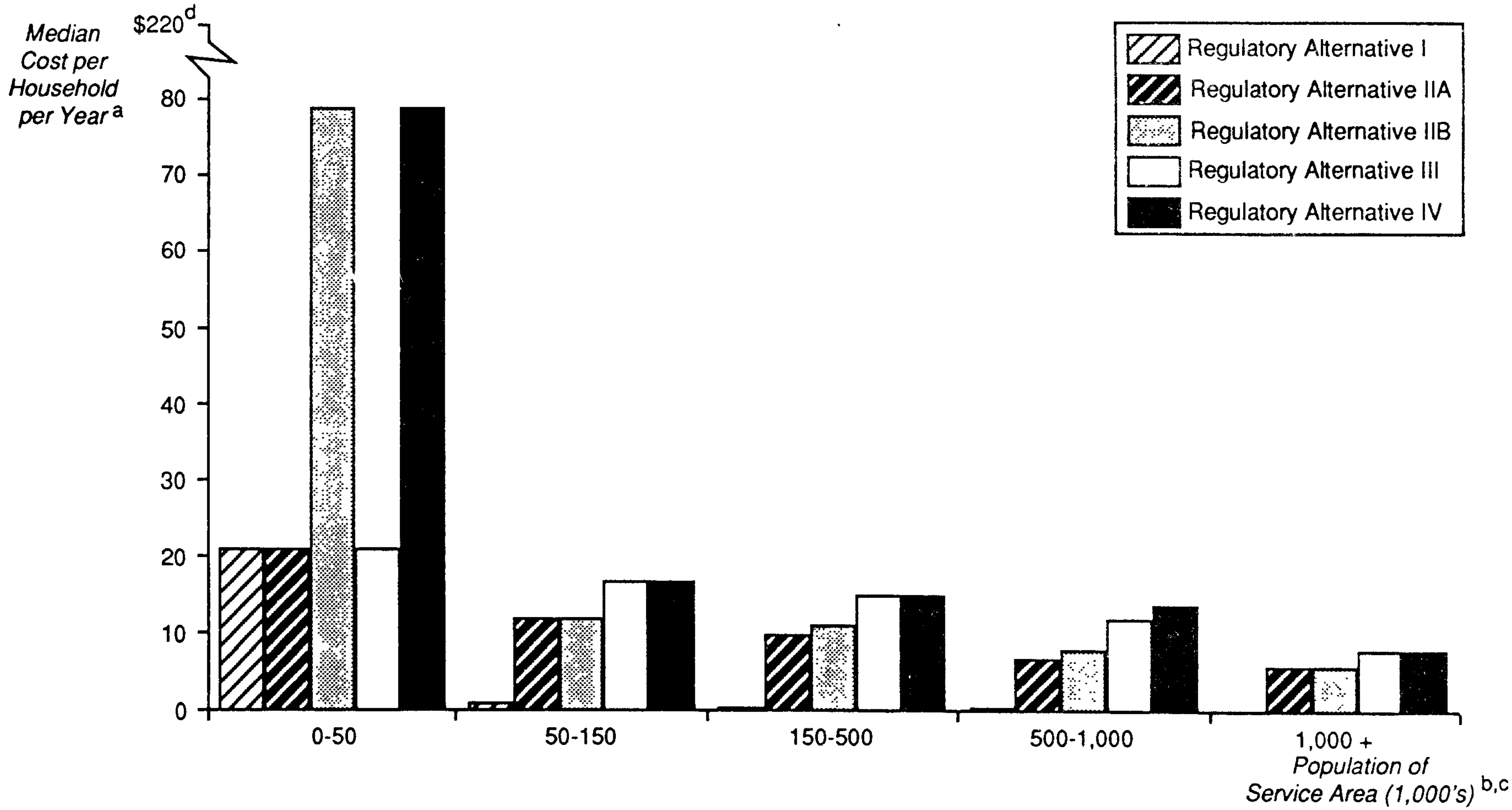
To assess impacts on governmental units, we identified the plants owned by municipalities or counties. For each of these public plants, data were collected from the 1982 Census of Governments, including the county's or municipality's annual capital expenditures, annual total tax revenue and total revenue, annual total expenditures, and annual sewerage and sanitation expenditures, as well as the county's or municipality's total debt outstanding and annual interest paid on the debt. These government expenditure and revenue figures were inflated from 1982 dollars to 1987 dollars using the State and Local Government Expenditure Deflator (*1988 Economic Report of the President*, p. 253). These data were used to estimate annual values for three government impact indices:

1. sum of the average sewerage and sanitation cost per household and the average control cost per household as a percent of median household income,

2. sum of total current debt service and additional debt service associated with the capital cost of control as a percent of total general revenues, and

3. control costs as a percent of total general expenditures.

The first two indices are adaptations of indices used in the Municipal Sector Study (U.S. EPA, 1988c). Exact duplication of the indices used in that study was impossible with the data available to us, so our analysis substituted measures of government activity similar in principle. The Sector Study indices are designed to measure a government entity's ability to meet additional financial obligations incurred due to the regulation. More specifically, the indices are designed to measure each government's ability to issue revenue bonds or obtain loans to finance the additional control costs. The third index is one used in the OSW Subtitle D Landfill RIA. It is a measure of the additional governmental cost burden associated with the regulation relative to the existing government commitments.



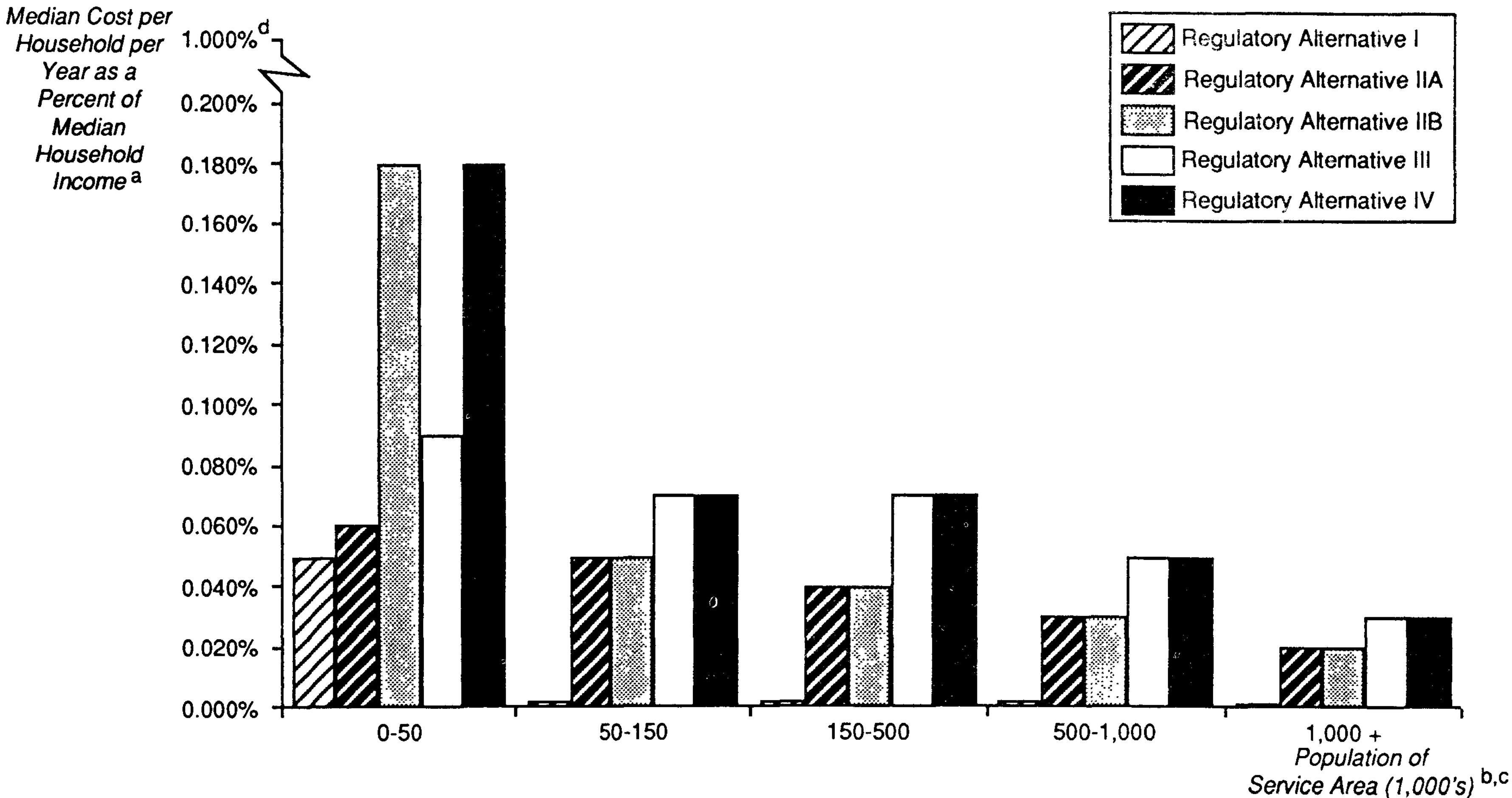
[a] Costs refer to control costs only; no baseline costs are included.

[b] Service areas with less than 2,500 total population were not included in the sample because census data for these service areas were not available.

[c] Service areas with implicit capacity utilization less than 40 percent for modular plants, less than 60 percent for other technologies, or greater than 400 percent for all technologies were not included in the sample. See text for discussion.

[d] Household impacts were defined as "severe" if average cost exceeds $220 per household per year.

Figure 8-3. Distribution of Household Impacts Under NSPSs by Service Area Population and Regulatory Alternative: Index 1



[a] Costs refer to control costs only; no baseline costs are included.

[b] Service areas with less than 2,500 total population were not included in the sample because census data for these service areas were not available.

[c] Service areas with implicit capacity utilization less than 40 percent for modular plants, less than 60 percent for other technologies, or greater than 400 percent for all technologies were not included in the sample. See text for discussion.

[d] Household impacts were defined as "severe" if average cost exceeds 1 percent of median household income per household per year.

Figure 8-4. Distribution of Household Impacts Under NSPSs by Service Area Population and Regulatory Alternative: Index 2

Indices of government unit impacts were only computed for some of the plants affected by the regulation. Our analysis naturally included only MWCs that could be identified as government owned. We further restricted our analysis to those plants for which ownership and service area were specified as being the same. In some cases, this meant that even though ownership was specified as one county, the plant may have actually served multiple counties, counties and municipalities, or multiple municipalities in one or more counties. As previously noted, assigning only one government unit to a plant may tend to overestimate government unit impacts for those MWCs that serve several jurisdictions by underestimating the financial base of the communities served. We thus treat this part of the analysis as a screening procedure, aimed at identifying potential problem communities. If assigning a single government unit to the MWC plant in our analysis does not give severe impacts, the full assignment of all relevant government units with their greater combined resources to the plant is unlikely to give severe impacts.

Only the model plant costs for public ownership were considered in our analysis of government impacts. The compliance costs were summed over all the public combustor plants in each county or municipality. While we were concerned that this reduction in the number of plants analyzed might distort the government impact analysis, the remaining 17 plants appeared to be fairly representative of the entire set in terms of population served, median income, and combustor technology.

To compute the impacts, we combined Census of Governments data associated with these 17 counties or municipalities with the control cost data for the affected plant. These impacts were compared to the "severity" measures adopted from the Sector Study and the OSW Landfill RIA. Using the Municipal Sector Study criterion, a governmental unit is defined as severely impacted if:

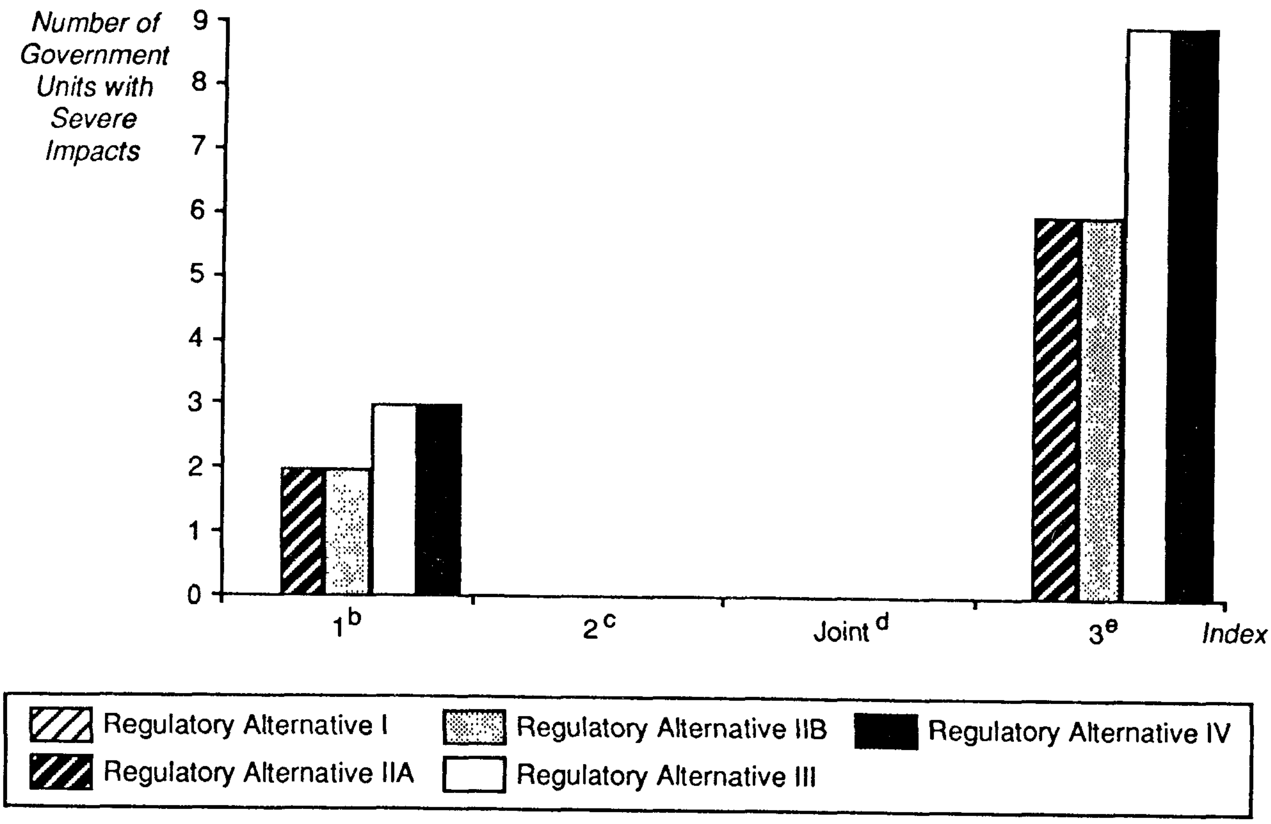
- the sum of the average sewerage and sanitation cost per household and the average control cost per household as a percent of median household income exceeds 1 percent, and

- the sum of total current debt service and additional debt service associated with the capital cost of compliance to the regulation as a percent of total general revenues exceeds 15 percent.

For the OSW Landfill RIA, the government impact is likely to be severe if:

- control costs as a percent of total general expenditures exceed 1 percent.

Figure 8-5 shows the preliminary results for our analysis using each of the indices as well as the joint criterion for the first two indices. Since the first and second criteria must be met



[a] Service areas with less than 10,000 total population were not included in the sample because census data for these service areas were not available.

[b] Index 1 is the sum of average sewerage and sanitation cost per household and the average control cost per household as a percent of median household income. The Municipal Sector Study (U.S. EPA, 1988d) sets 1 percent as the criterion for severe impacts under this index.

[c] Index 2 is the sum of total current debt service and additional debt service associated with compliance to the regulation as a percent of total general revenues. The Municipal Sector Study (U.S. EPA, 1988d) sets 15 percent as the criterion for severe impacts under this index.

[d] Using the Municipal Sector Study criteria, both index 1 and index 2 must be exceeded to indicate severe impacts.

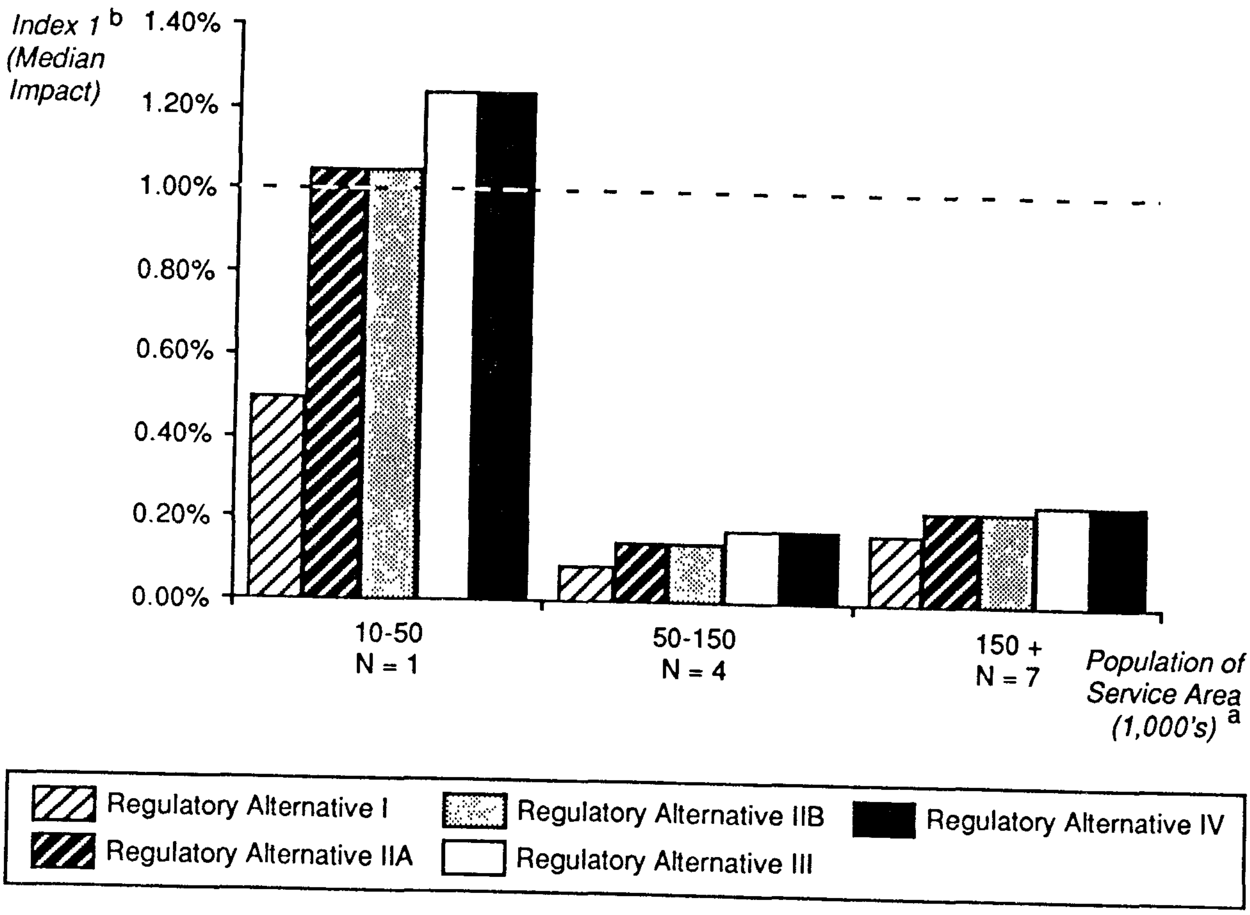
[e] Index 3 measures control costs as a percent of total general expenditures. The OSW Landfill RIA sets 1 percent as the criterion for severe impacts under this index

Figure 8-5. Distribution of Government Impacts Under NSPSs: Preliminary Screening Results [a]

together to indicate severe impacts, no government units had severe impacts under the joint criterion. Under the third criterion nine governments were identified as having severe impacts in our analysis. Of these, however, the screening procedure revealed that only 3 service areas had estimated waste generation that roughly matched the capacity of the associated plants (based on implied capacity utilization between 40 percent and 400 percent for modular plants and 60 percent and 400 percent for all other plants).

Given this indication that the government impacts might indeed be severe under one of the criteria, we examined the service and financial conditions of each community we identified as having severe impacts. This inquiry revealed that more than one government jurisdiction was served by the plant(s) in all nine cases where severe impacts were indicated. In many cases, the financial base in our analysis represented only a small fraction of the actual financial base served by the combustor. Adding the resources of these government units together would result in smaller impact measures and reduction of the index below the "severe" threshold. We note, however, that because of data limitations, we could not compute impact indices for plants serving government entities representing service areas with a population of 10,000 or less.

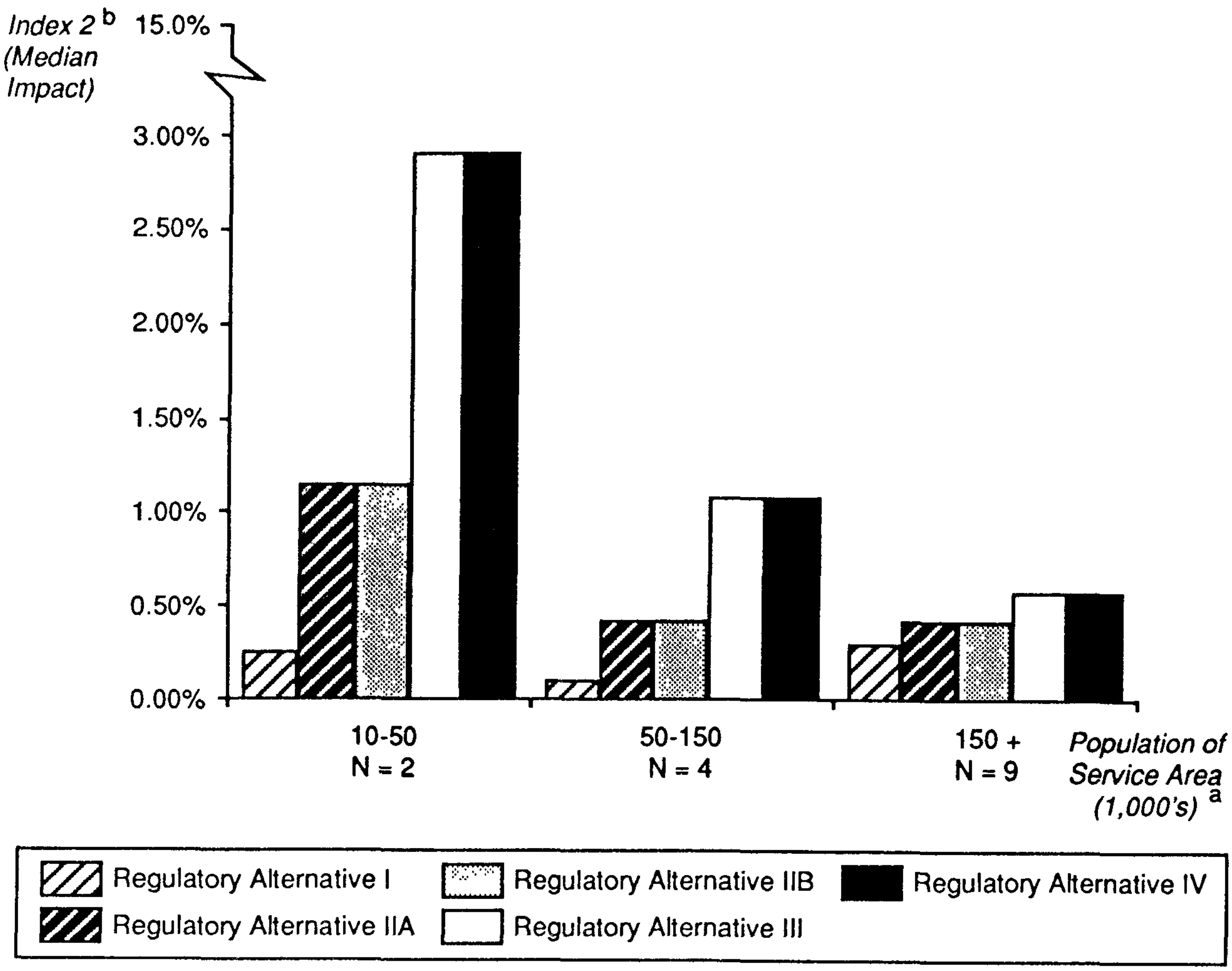
Using county and municipality population data, we divided the service areas into population size categories. Figures 8-6, 8-7, and 8-8 examine the relationship between the impact ratios and the county or municipality size. Some evidence of an inverse relationship between the magnitude of the impact variable and population size appears to exist. Regulatory Alternatives III and IV, with more stringent controls on large combustors, tend to have the greatest impact on government units.



[a] Service areas with less than 10,000 total population were not included in the sample because census data for these service areas were not available.

[b] Index 1 is the sum of average sewerage and sanitation cost per household and the average control cost per household as a percent of median household income. The Municipal Sector Study (U.S. EPA, 1988d) sets 1 percent as the criterion for severe impacts under this index.

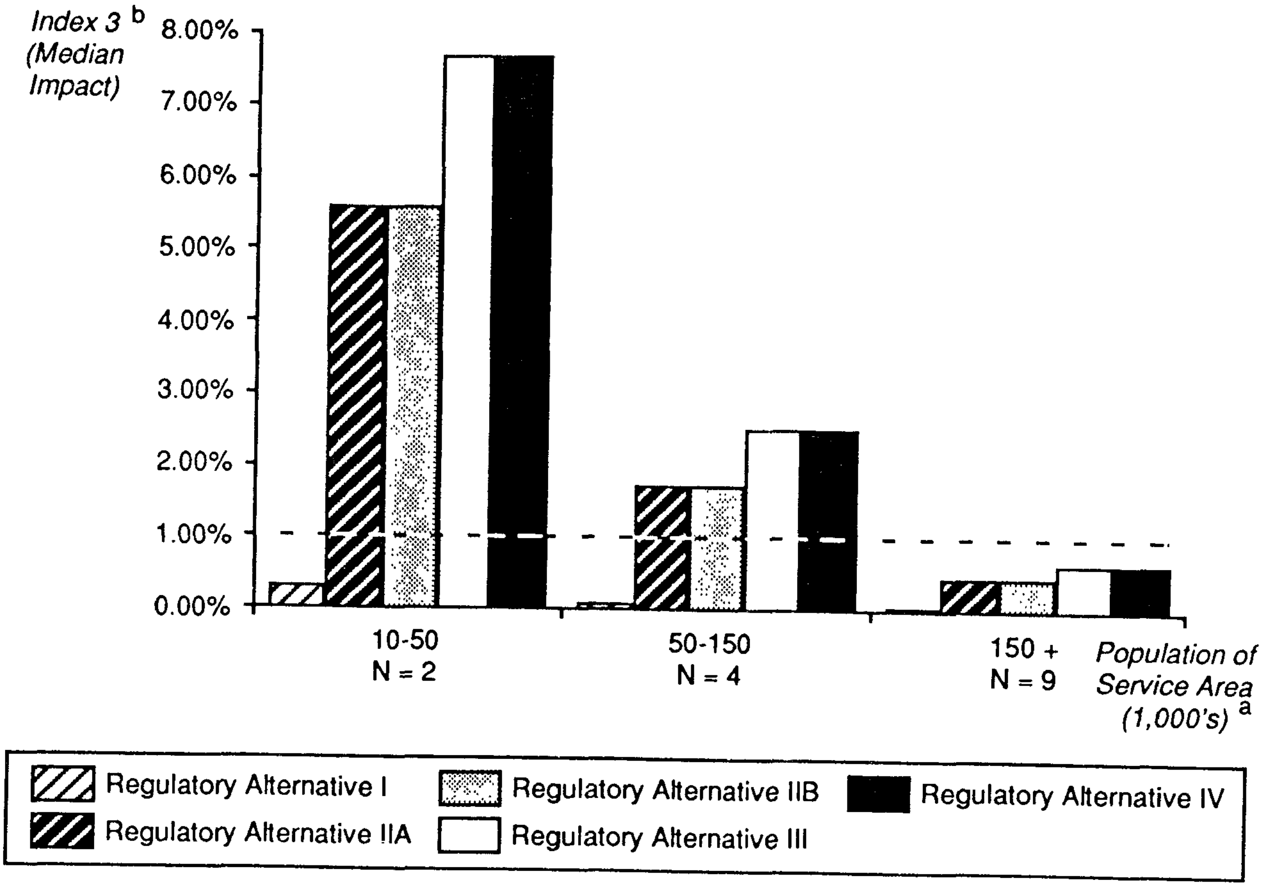
Figure 8-6. Distribution of Government Impacts Under NSPSs by Service Area Population and Regulatory Alternative: Index 1



[a] Service areas with less than 10,000 total population were not included in the sample because census data for these service areas were not available.

[b] Index 2 is the sum of total current debt service and additional debt service associated with compliance to the regulation as a percent of total general revenues. The Municipal Sector Study (U.S. EPA, 1988d) sets 15 percent as the criterion for severe impacts under this index.

Figure 8-7. Distribution of Government Impacts Under NSPSs by Service Area Population and Regulatory Alternative: Index 2



[a] Service areas with less than 10,000 total population were not included in the sample because census data for these service areas were not available.

[b] Index 3 measures control costs as a percent of total general expenditures. The OSW Landfill RIA sets 1 percent as the criterion for severe impacts under this index

Figure 8-8. Distribution of Government Impacts Under NSPSs by Service Area Population and Regulatory Alternative: Index 3

CHAPTER 9
SENSITIVITY ANALYSIS

Social costs were estimated using a two-stage discounting procedure (see Table 9-1). Annualized social costs are the sum of capital costs, annualized at 10 percent, and operating costs. Present values are calculated by applying a 3 percent discount rate to total annualized values. EPA has not officially adopted the use of the two-stage discount procedure. In addition, continuing debate surrounds the appropriate discount rate to use in any procedure. To show how alternative views of discounting affect the results of this analysis, the social costs were recalculated using single discount rates: 10 percent in one case and 3 percent in another. The results are shown in Tables 9-2 and 9-3, respectively.

Average capacity utilization values reported in the *1988-89 Resource Recovery Yearbook* (Gould, 1988) were adopted for the calculation of most of the model plant baseline waste flows. Capacity utilization estimates reported by Radian (EPA, 1989c) averaged as much as 8 percent higher than those used in this report. Table 9-4 presents scaling factors calculated using higher capacity utilization. These factors are used to calculate national cost impacts in Table 9-5 and emission reductions in Table 9-6. Table 9-5 reports Scenario I national social costs using the two-step discounting procedure described above with the higher capacity utilization values. Table 9-6 reports Scenario I baseline emissions and emissions reductions under each regulatory alternative with the higher capacity utilization values. Using a higher capacity utilization results in no change in Scenario I baseline emissions or emissions reductions because even though the number of plants in each model plant category is reduced, total waste flow processed by MWC does not change. Calculation of Scenario III costs and emissions reductions would require the development of control costs based on higher capacity utilization and the introduction of these costs into the spreadsheet provided by Bentley and Spitz (1989) containing choice equations.

TABLE 9-1. NSPSs NATIONAL COST IMPACTS: SOCIAL COSTS USING A TWO-STEP DISCOUNTING PROCEDURE (1987 $)[a]

Scenario and Regulatory Alternative	Capital Costs ($10^6)	Present Value of Social Costs ($10^6)	Annualized Social Costs ($10^6/yr)	Annualized Social Costs per Mg MSW[b] ($/Mg)
Scenario I				
Regulatory Alternative I	30.5	126	6.41	0.46
Regulatory Alternative IIA	183	1,190	97.2	6.99
Regulatory Alternative IIB	216	2,260	115	7.70
Regulatory Alternative III	514	2,930	150	10.80
Regulatory Alternative IV	548	3,290	168	11.20
Scenario III				
Regulatory Alternative I	29.7	123	6.26	0.46
Regulatory Alternative IIA	121	1,320	67.6	6.86
Regulatory Alternative IIB	149	1,610	82.0	7.69
Regulatory Alternative III	321	1,840	93.8	10.60
Regulatory Alternative IV	347	2,110	107	11.10

[a] Annualized social costs are the sum of capital costs, annualized at *10 percent*, and annual operating costs. Present values are computed as the present value of these annualized costs using a *3 percent* rate of discount.

[b] Computed by dividing total annualized cost by the estimated amount of MSW processed per year by MWC.

TABLE 9-2. NSPSs NATIONAL COST IMPACTS: SOCIAL COSTS USING A 10 PERCENT DISCOUNT RATE (1987 $)

Scenario and Regulatory Alternative	Capital Costs ($$10^6$)	Present Value of Social Costs ($$10^6$)	Annualized Social Costs ($$10^6$/yr)	Annualized Social Costs per Mg MSW[a] ($/Mg)
Scenario I				
Regulatory Alternative I	30.5	60.5	6.41	0.46
Regulatory Alternative IIA	183	917	97.2	6.99
Regulatory Alternative IIB	216	1,090	115	7.70
Regulatory Alternative III	514	1,410	150	10.80
Regulatory Alternative IV	548	1,580	168	11.20
Scenario III				
Regulatory Alternative I	29.7	58.9	6.26	0.46
Regulatory Alternative IIA	121	637	67.6	6.86
Regulatory Alternative IIB	149	773	82.0	7.69
Regulatory Alternative III	321	884	93.8	10.60
Regulatory Alternative IV	347	1,010	107	11.10

[a] Computed by dividing total annualized cost by the estimated amount of MSW processed per year by MWC.

TABLE 9-3. NSPSs NATIONAL COST IMPACTS: SOCIAL COSTS USING A 3 PERCENT DISCOUNT RATE (1987 $)

Scenario and Regulatory Alternative	Capital Costs ($$10^6$)	Present Value of Social Costs ($$10^6$)	Annualized Social Costs ($$10^6$/yr)	Annualized Social Costs per Mg MSW[a] ($/Mg)
Scenario I				
Regulatory Alternative I	30.5	97.2	4.96	0.36
Regulatory Alternative IIA	183	1,730	88.5	6.37
Regulatory Alternative IIB	216	2,050	105	7.01
Regulatory Alternative III	514	2,450	125	9.00
Regulatory Alternative IV	548	2,770	142	9.46
Scenario III				
Regulatory Alternative I	29.7	94.8	4.84	0.36
Regulatory Alternative IIA	121	1,210	61.8	6.28
Regulatory Alternative IIB	149	1,470	74.9	7.02
Regulatory Alternative III	321	1,540	78.5	8.87
Regulatory Alternative IV	347	1,780	90.9	9.43

[a] Computed by dividing total annualized cost by the estimated amount of MSW processed per year by MWC.

TABLE 9-4. SCENARIO I SCALING FACTORS CALCULATED USING A HIGHER CAPACITY UTILIZATION[a,b]

Model Plant #	Model Plant Type*	Model Plant Capacity (Mg/day)	Scenario I Scaling Factors[c]
1	MB/WB (small)	180	16.81
2	MB/WW (mid-size)	730	6.75
3	MB/WW (large)	2,040	7.88
4	MB/REF	450	3.00
5	MB/RC	950	3.00
6	RDF	1,810	4.88
7	RDF/CF	1,810	3.00
8	MOD/EA	220	3.00
9	MOD/SA (small)	45	1.80
10	MOD/SA (mid-size)	90	6.38
11	FBC/BB	820	1.88
12	FBC/CB	820	4.13
	Model Plant Total		62.51

[a] Scenario III scaling factors differ with each regulatory alternative.

[b] Tables 3-2 describes each of the model plants listed here.

[c] These scaling factors are based on the annual operating hours reported by Radian (EPA, 1989c) with an adjustment for a model plant #7 which co-fires 50 percent wood. Capacity utilization adopted in the Radian report was in many cases greater than that used in the baseline and scenarios of this impact analysis.

TABLE 9-5. NSPSs NATIONAL COST IMPACTS: SOCIAL COSTS USING A HIGHER CAPACITY UTILIZATION (1987 $)[a]

Scenario and Regulatory Alternative	Capital Costs ($$10^6$)	Annualized Social Costs ($$10^6$/yr)[b]	Annualized Social Costs per Mg MSW[c] ($/Mg)
Scenario I			
Regulatory Alternative I	28.1	6.10	0.44
Regulatory Alternative IIA	168	96.3	6.93
Regulatory Alternative IIB	200	114	7.63
Regulatory Alternative III	472	145	10.40
Regulatory Alternative IV	504	163	10.90

[a] Calculated based on annual hours of operation as reported by Radian (EPA, 1989c) with an adjustment for a model plant #7 which co-fires 50 percent wood. Capacity utilization adopted in the Radian report was in many cases greater than that used in the baseline and scenarios of this impact analysis.

[b] Annualized social costs are the sum of capital costs, annualized at *10 percent*, and annual operating costs.

[c] Computed by dividing total annualized cost by the estimated amount of MSW processed per year by MWC.

TABLE 9-6. NSPSs NATIONAL BASELINE EMISSIONS AND EMISSION REDUCTIONS (Mg PER YEAR): HIGHER CAPACITY UTILIZATION[a]

Scenarios and Regulatory Alternatives	CDD/CDF	CO	PM	SO_2	HCl	Pb	Ash
Scenario I							
Baseline Emissions	0.0152	5,470	7,540	42,000	49,300	127	3,700,000
Emissions Reductions							
Regulatory Alternative I	0	0	5,220	0	0	88.5	-154,000
Regulatory Alternative IIA	0.0107	0	5,220	18,300	36,700	108	-383,000
Regulatory Alternative IIB	0.0115	0	5,960	19,300	39,500	124	-401,000
Regulatory Alternative III	0.0139	0	5,220	35,400	44,400	108	-314,000
Regulatory Alternative IV	0.0146	0	5,960	36,400	47,200	124	-332,000

[a] Calculated based on annual hours of operation as reported by Radian (EPA, 1989c) with an adjustment for a model plant #7 which co-fires 50 percent wood. Capacity utilization adopted in the Radian report was in many cases greater than that used in the baseline and scenarios of this impact analysis.

KEY: polychlorinated dibenzo-*p*-dioxins and dibenzofurans (CDD/CDF), carbon monoxide (CO), particulate matter (PM), sulfur dioxide (SO_2), hydrogen chloride (HCl), and lead (Pb).

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APPENDIX A

ESTIMATION OF THE REAL DISCOUNT RATE FOR PRIVATE FIRMS AND PUBLIC ENTITIES

CONTENTS

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APPENDIX A

ESTIMATION OF THE REAL DISCOUNT RATE FOR PRIVATE FIRMS AND PUBLIC ENTITIES

A.1 INTRODUCTION

The cash flow model introduced in Chapter 3 is needed to determine the cost associated with meeting an emission standard or guideline. The model is also used to predict a decision maker's response when a number of options for meeting a regulation are available.

Two forms of the model were presented: one for a private firm and one for a public entity like a municipality or a solid waste authority. The reason for this distinction is that these forms of organization face very different financial conditions due to the effect of differing tax treatment of their incomes and expenditures. Not only are the cash flow models different, but the financial parameters used in the models are also different. In particular, the real discount rates used in the private and public (municipal) cash flow models differ. In this appendix we describe how the different real discount rates for private and public (municipal) entities used in this analysis were estimated.

This section also discusses some of the problems and issues—such as inflationary expectations and risk and liquidity premiums—associated with both estimating and applying cost of capital values. Additional information on estimation and using cost-of-capital values for regulatory analyses may be found in an RTI report by Anderson, Mims, and Ross (RTI, 1987).

A.2 PRIVATE COST OF CAPITAL

The private discount rate is the "time value of money" used by firms to represent the cost to them of investing funds today in anticipation that these expenditures will yield revenues sometime in the future. The private discount rate is therefore often referred to as the "cost of capital."

For a private firm, the cost of capital can be the rate of return on an alternative investment or, if the firm has access to credit or equity markets, the lending rates prevailing in those markets. Inasmuch as a firm with access to capital funds would find it profitable to invest in any opportunity where the rate of return exceeds the cost of capital in credit and equity markets, these market-based values determine the cost of capital.

A.2.1 The Weighted Average Cost of Capital

Most private firms finance new investments from two sources of capital: debt and equity. The term "weighted average cost of capital" is used to denote the fact that the firm's overall cost of capital is a weighted average of the costs of debt and equity. Debt financing is generally carried out by issuing long-term bonds. Equity financing occurs when firms retain earnings and issue common stock. Other sources of capital are usually insignificant in comparison to these two sources and therefore will not be discussed here.

The before-tax cost of debt is the interest rate a firm must pay on long-term debt. This rate is equal to the yield to maturity (YTM) on the firm's long-term bonds. YTM is based on current bids for the bonds in the bond market. YTM must be used rather than the rate at which past debt was issued because the firm's *current* cost of capital is the relevant interest rate in new investment decisions.

Interest paid by corporations with current revenues is tax deductible; therefore the after-tax cost of debt is the true cost of debt for the firm. The after-tax cost of debt can be calculated by multiplying the before-tax cost of debt by one minus the combined state and federal marginal corporate tax rate (t).

The cost of equity is much more difficult to estimate. The cost of equity is the rate of return that is required by the holders of the firm's common stock. This rate of return must be earned to ensure that the market price of common stock remains unchanged. Estimation of the cost of equity is discussed in detail below.

Once the cost of debt and equity have been computed, however, they can be combined to estimate the overall or weighted average cost of capital (WACC) for the firm. In equation form:

$$WACC = (1-t)\, r_d(D/V) + r_e(E/V) \qquad (A.1)$$

where

t = marginal corporate tax rate,

r_d = before-tax cost of debt,

D= value of firm's debt,

E = value of firm's equity,

V = total value of firm (D + E), and

r_e= cost of equity.

This is the appropriate discount rate for all of the firm's investments even though any specific project could conceivably be financed entirely by one source. The WACC formula assumes that the firm's debt/equity ratio will remain constant over time.

Once the firm's WACC has been estimated, then the average cost of capital for the municipal solid waste management industry can be calculated. This value for the industry can be used in conjunction with a discounted cash flow model and estimates of expected expenditures (including taxes) and revenues to assess the relative attractiveness of a given investment using a net present value criterion.

A.2.2 Cost of Equity

Three methods of estimating the cost of equity capital for use by private firms are discussed below: the Capital Asset Pricing Model (CAPM), the Bond Rate Plus Four method, and the Dividend Growth method.

In equation form, CAPM can be expressed as follows:

$$r_e = r_f + B[r_m - r_f] \qquad (A.2)$$

r_e = cost of equity,

r_f = risk-free rate of return (long-term treasury bonds),

r_m = rate of return in the equity market generally (i.e., S&P 500), and

B = Beta, a measure of the relative risk of the equity asset.

Beta values of stocks are readily available through several sources such as *The Value Line Investment Survey*.

The second method for estimating the cost of equity is called the "bond rate plus four" method. In this method one adds 4 percentage points to the interest rate on a firm's long-term debt to obtain the estimated return on equity. This is an ad hoc method that provides only rough estimations of a firm's cost of equity and should only be used in conjunction with other methods.

Tied as it is to the cost of debt, however, it tends to reflect the reasonable assumption that firms with risky debt will also have risky and high cost equity.

A third method of estimating a firm's cost of equity is the Dividend Growth Method (DGM). DGM is based on the theory that the current price of a share of stock is equal to the present value of expected future dividend payments. This can be expressed as:

$$P_0 = \frac{D_1}{r_e - g} \qquad (A.3)$$

where

P_0 = current price of stock,

D_1 = expected dividend next year,

r_e = firm's cost of equity, and

g = expected annual growth rate of dividends.

P_0 is the current price of stock as quoted in any newspaper; estimates of D_1 can be found in many sources, such as *The Value Line Investment Survey;* and g can be estimated from historical data on dividend growth. With these values in hand it is a simple matter to calculate the cost of equity, using the DGM.

A.2.3 Estimation of the WACC

The data and calculations used in estimating the WACC by the CAPM are presented in Table A-1. In these calculations, a federal corporate tax rate of 34 percent is used. As an approximation, a state corporate tax rate of 7 percent is used to derive an effective tax rate of approximately 39 percent. The beta values (B) used to calculate the cost of equity are the overall betas for the firms in Table A-1. The overall company beta is a measure of a firm's overall undiversifiable risk, not the more specific municipal risk of waste management projects; betas specific to waste management activities of the firms are not available.

As shown in Table A-1, using the average r_e found by the CAPM and the average yield of bonds as rated by *Standard and Poors* (Table A-2), the average WACC is 14.11 percent, with a range for individual firms of 11.43 percent to 16.80 percent.[1]

[1] The only difference between the methods discussed above and their application in this appendix lies in computing the cost of debt, r(d). Direct information on the yield to maturity for the long-term instruments of the firms in

The calculations using the Bond Rate Plus Four method are presented in Table A-3. As can be seen, the average return on long-term debt for the 12 firms in our sample is 11.02 percent. The resulting r_e using the Bond Rate Plus Four method is 15.02 percent. The average WACC is 12.81 percent with a range of 10.20 percent to 15.27 percent for individual firms in the sample.

Table A-4 presents WACC calculations using the DGM methodology to find the return on equity. The current price of stock is the price of the stock on January 14, 1988. D_1 is the expected annual dividend as found in *The Value Line Investment Survey*. The expected growth rate in the stock was derived from *The Value Line Investment Survey* as the growth rate expected over the next 12 months. As can be seen, the industry average WACC using this methodology is estimated to be 8.81 with a range of 5.18 to 14.37 percent. The DGM therefore results in much lower WACC estimates than the other two methods.

The three estimates of WACC are simple arithmetic means and are not weighted by market share of each firm. In addition, the firms included in the analysis are only those that currently own or supply municipal waste management facilities, are publicly traded, and are large enough to have the necessary financial statistics available. The WACC values calculated using the above methodologies are nominal and not real WACC. The effects of expected inflation and the underlying real cost of capital are discussed below.

A.3 PUBLIC COST OF CAPITAL

Public entities do not have equity investors, and some holders of certain types of municipal debt do not pay income tax on interest received. Thus, the cost of capital values in the financial markets appropriate to a private firm are not the relevant cost of capital values for municipalities.

Public entities that manage municipal wastes usually finance new projects by issuing municipal bonds. Revenue bonds are generally used rather than general obligation bonds. Thus, the cost of debt is slightly higher than the rate on long-term general obligation municipal bonds.

A very broad range of public entities own municipal waste management facilities (Gould, 1986). Thus, average yields on municipal revenue bonds can be used as the cost of capital for public entities that manage municipal waste. According to the *Merrill Lynch Bond Index* for

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Table A-1 varied greatly for debt instruments across sources because of differences in reporting periods. We used the S&P bond ratings for each firm's bonds to find the yield to maturity based on the average yield in each rating category. The yields for bond ratings AAA through BBB are directly from Standard and Poors while the yields for lower ratings were estimated based on a previous analyses performed by RTI (1987).

January 14, 1988, the yield on long-term municipal revenue bonds is 8.40 percent. This is also the average over the past year.

A.4 INFLATION AND THE REAL COST OF CAPITAL

The WACCs estimated above for private and public entities are nominal rates of discount. To find real or inflation-adjusted cost of capital, we must estimate investors' expected rate of inflation over the long term.

The expected change in the rate of inflation over the next 20 years can be approximated from the difference in current short-term and long-term interest rates after adjustment for investors' liquidity preferences. Liquidity preference has been estimated to be about 1 percent. However, the current difference between short- and long-term interest rates is observed to be 1.89 percent (9.11 - 7.22). This indicates that inflation is expected to be approximately 0.89 percentage points over the current level for the next 20 years.

Current inflation expectations over the short term generally match recent actual rates of inflation. Recent actual rates of inflation have roughly averaged 3.50 percent (see Standard & Poors Statistical Service). Therefore the expected average rate of inflation over the next 20 years is estimated to be 4.39 percent (0.0350+0.0089).

Another way of estimating the expected rate of inflation is to assume that the real discount rates determined by past nominal rates of return and inflation are still being earned by today's investors. Historically, real discount rates appear to have been in the 3 to 4 percent range. Applying the 4 percent figure to virtually risk-free, long-term treasury bills circulating today yields an estimate of the expected rate of inflation of 4.91 percent [(0.0911 - 0.04)/1.04].

Estimates of the private and public real WACC under different estimates of expected inflation and the nominal WACC are shown on Table A-5. The wide range in values highlights the uncertainty associated with estimation of a real WACC, making selection of a particular value for use in this impact analysis somewhat arbitrary. Given this uncertainty, rounded real WACC values of 8 and 4 were selected for private and public entities respectively. The former is in the neighborhood of estimates provided by two of the three methods used to estimate the cost of equity capital. The latter is the rounded value of the average of the two estimates of the public entity real WACC in Table A-5. One should note again that these estimates are approximate and that the real WACC will vary substantially across individual firms and public entities.

A.5 SOCIAL RATE OF DISCOUNT

The WACCs calculated above are not equal to the social rate of discount used in determining the social costs in an economic impact analysis (see Section 6.4 above). While the cost of capital calculated above is the opportunity cost of investing in a particular project, the social rate of discount used in calculating social costs is the time value of money on the foregone consumption and investment opportunities of society as a whole. Differences arise due to taxes on investment income, transaction costs, and other "wedges" that distinguish private from social rates of discount.

TABLE A-1. CAPITAL ASSET PRICING METHOD: DATA AND WACC CALCULATIONS FOR PRIVATE ENTITIES IN THE MUNICIPAL WASTE MANAGEMENT INDUSTRY

Firm[a]	B	Rating	D/V	r_d (%)	r_e (%)	WACC (%)
Allied Signal	0.90	A	0.39	10.69	15.50	12.01
Ashland Oil	0.85	A	0.34	10.69	15.15	12.23
Boeing	0.95	AA	0.05	10.07	15.85	15.37
Comb. Eng.	1.05	A	0.25	10.69	16.55	14.05
Dravo	1.30	BBB	0.20	11.22	18.30	16.02
Foster Wheeler	1.15	BBB	0.29	11.22	17.25	14.25
Katy Industries	1.25	B	0.11	12.23	17.95	16.80
McDermott	1.05	BBB	0.53	11.22	16.55	11.43
Ogden	1.00	BBB	0.38	11.22	16.20	12.66
United Ind.	1.05	BBB	0.12	11.22	16.55	15.39
Westinghouse	1.30	AA	0.49	10.07	18.30	12.36
Zurn	1.20	BB	0.08	11.71	17.60	16.77
Industry Average						14.11

[a] Firms in this list are compiled from trade publication discussion of industry participants for which the requisite financial data are available. Most of these firms build and operate municipal waste facilities, especially combustors. Financial statistics for small private owners and operators of waste disposal facilities are not publicly available.

Sources: *Standard and Poors, Inc.*, December 1987; *Standard and Poors, Inc.*, September 1987; *Moody's Inc.*, 1987

TABLE A-2. STANDARD & POORS BOND RATINGS AND YIELDS

Rating	Average Yield (%)
AAA	9.71
AA	10.07
A	10.69
BBB	11.22
BB	11.71
B	12.23
CCC	12.74

Sources: *Standard & Poors Statistical Service,* December 1987

TABLE A-3. "BOND RATE PLUS FOUR" METHOD: WACC CALCULATIONS FOR PRIVATE ENTITIES IN THE MUNICIPAL SOLID WASTE MANAGEMENT INDUSTRY

Firm	r_d (%)	r_e (%)	D/V	WACC (%)
Allied Signal	10.69	14.69	.39	11.52
Ashland Oil	10.69	14.69	.34	11.93
Boeing	10.07	14.07	.05	13.68
Combust. Eng.	10.69	14.69	.25	12.66
Dravo	11.22	15.22	.20	13.55
Foster Wheeler	11.22	15.22	.29	12.80
Katy Industries	12.23	16.23	.11	15.27
McDermott	11.22	15.22	.53	10.80
Ogden	11.22	15.22	.38	12.05
United Indust.	11.22	15.22	.12	14.22
Westinghouse	10.07	14.07	.49	10.20
Zurn	11.71	15.71	.08	15.03
Industry Average				12.81

Sources: *Standard and Poors Inc.*, December 1987; *Standard and Poors Inc.*, September 1987; *Moody's Inc.*, 1987

TABLE A-4. DIVIDEND GROWTH MODEL METHOD: DATA AND WACC CALCULATIONS FOR PRIVATE ENTITIES IN THE MUNICIPAL SOLID WASTE MANAGEMENT INDUSTRY

Firm	r_d (%)	P_0	D_1	g	r_e (%)	D/V	WACC (%)
Allied Signal	10.69	31	2.20	5.5	12.60	.39	10.24
Ashland Oil	10.69	56	1.00	9.5	11.29	.34	9.68
Boeing	10.07	46	1.75	11.00	14.80	.05	14.37
Combust. Eng.	10.69	29	1.00	5.00	8.45	.25	7.98
Dravo	11.22	13	0.50	1.50	5.35	.20	5.65
Foster Wheeler	11.22	15	0.44	2.00	4.93	.29	5.50
McDermott	11.22	16	1.00	-3.00	3.25	.53	5.18
Ogden	11.22	29	1.20	10.00	14.14	.38	11.38
United Indust.	11.22	13	0.64	4.50	9.42	.12	9.12
Westinghouse	10.07	50	2.15	12.50	16.80	.49	11.60
Zurn	11.71	23	0.72	3.00	6.13	.08	6.22
Industry Average							8.81

Sources: *Standard and Poors Inc.*, December 1987; *Standard and Poors Inc.*, September 1987; *Moody's Inc.*, 1987; *The Value Line Investment Survey, January 1988*

TABLE A-5. ESTIMATED REAL WEIGHTED AVERAGE COST OF CAPITAL (PERCENT)

	Weighted Average Cost of Capital Method	4.39% Expected Inflation	4.91% Expected Inflation
Private Entities			
	Capital Asset Pricing Model	9.31	8.77
	Bond Rate Plus Four Method	8.07	7.53
	Dividend Growth Model	4.23	3.72
Public Entities			
	Long-Term Revenue Bonds	3.84	3.33