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Data Summary of Municipal Solid Waste Management Alternatives

Volume II: Exhibits

SRI International
Menlo Park, California

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Report Organization

This report, *Data Summary of Municipal Solid Waste Management Alternatives*, comprises 12 separately bound volumes. Volume I contains the report text. Volume II contains supporting exhibits. Volumes III through X are appendices, each addressing a specific MSW management technology. Volumes XI and XII contain project bibliographies. The document control page at the back of this volume contains contacts for obtaining copies of the other volumes.

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PREFACE

This report provides data for use in evaluating the proven technologies and combinations of technologies that might be considered for managing municipal solid waste (MSW). It covers five major methods for MSW management in common use today:

- Landfilling
- Mass combustion for energy recovery
- Production of refuse-derived fuel (RDF)
- Collection/separation of recyclables
- Composting.

It also provides information on three MSW management technologies that are not widely used at present:

- Anaerobic digestion
- Cofiring of MSW with coal
- Gasification/pyrolysis.

To the extent possible with available reliable data, the report presents information for each proven MSW technology on:

- Net energy balances
- Environmental releases
- Economics.

In addition to data about individual operations, the report presents net energy balances and inventories of environmental releases from selected combined MSW management strategies that use two or more separate operations.

The scope of the report extends from the waste's origin (defined as the point at which the waste is set out for collection), through transportation and processing operations, to its final disposition (e.g., recycling and remanufacturing, combustion, or landfilling operations). Data for all operations are presented on a consistent basis: one (1) ton of municipal (i.e., residential, commercial, and institutional) waste at the collection point. The data provided in tables in this report are also available in a spreadsheet that allows the user to modify the information and to tailor the combination strategies to fit a particular need. In the process of developing the data presented here, one goal was to identify where gaps in the available information exist as a guide to future data collection and research efforts.

Selection of an MSW management plan may be influenced by many factors, in addition to the technical performance and economics of each option. The importance of or emphasis on each of these factors is likely to differ for each jurisdiction. The factors below fall into this category, but were excluded from the scope of this report:

- Ecological impacts
- Health risks
- Social and other values
- Specific jurisdictional circumstances.

The MSW technologies covered in this report do not exhaust the plausible components of waste management strategies. For example, many communities have initiated efforts to decrease the amount of waste that must be handled by promoting source reduction and waste minimization, including backyard composting, but data on those programs are not analyzed here.

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Exhibit I

PROCESS ECONOMICS OF MUNICIPAL SOLID WASTE MANAGEMENT TECHNOLOGIES

This exhibit reviews and summarizes the capital investments and operation and maintenance (O&M) costs of municipal solid waste (MSW) management systems and process modules. Those costs were extracted from published data and various literature sources, particularly from the extensive Government Advisory Associates data base, which was used to derive much of the data in Appendixes A through H.

TECHNOLOGY OPTIONS

Figure I.1 is a block flow diagram showing the various technologies that were evaluated for municipal solid waste management. The technologies include:

- Mass burn
- Refuse-derived fuel (RDF)
- Landfill
- Materials recovery and recycling
- Composting
- Anaerobic digestion
- Cofiring RDF with coal
- Gasification/pyrolysis.

This exhibit provides a basis on which to compare the plant investment and O&M costs for the various technologies covered in this report.

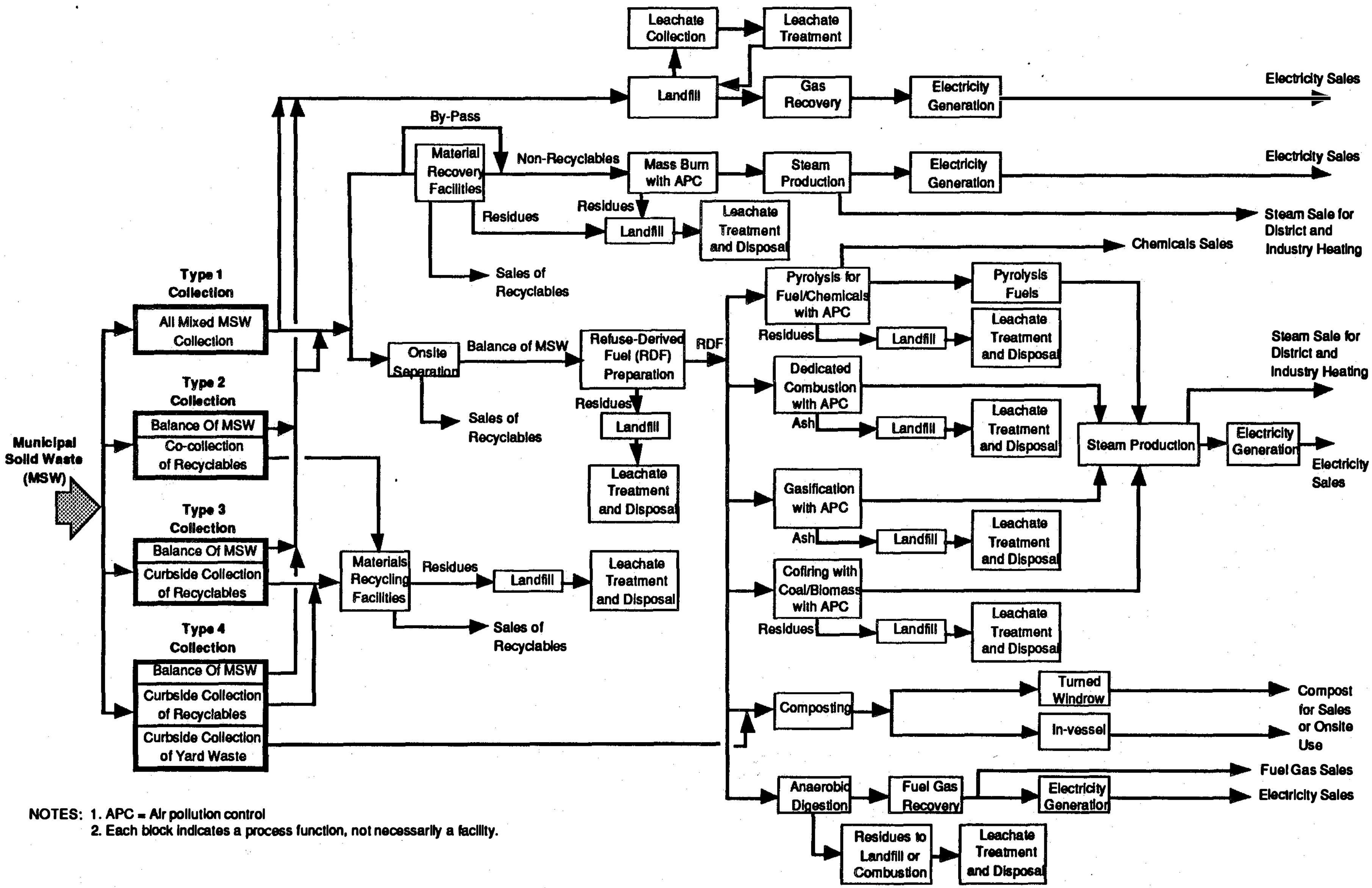
GENERAL ECONOMICS

Methodology

Published cost data on MSW management are somewhat fragmentary; in many cases, they are also too inconsistent to permit direct comparison of the economics of various technologies. These inconsistencies result from a large number of site-specific and cost allocation variations. For example, the finance charge for capital investment for a given MSW management project is significantly affected by the prevalent interest rate at the time of project financing. In situations in which the employed technologies are still experimental, the developmental costs tend to skew the real capital investment. Over time, the best available control technologies (BACTs) advance progressively, and that progress affects the capital costs of current and future projects. Moreover, capital investment in general would be affected by the type and composition of the wastes and the plant site conditions. Similarly, the operation and maintenance (O&M) costs are affected by site-specific conditions such as labor rates, labor contracts, safety rules, the size of the crew, and so on. Tipping fees generally reflect the capital and O&M costs of a facility. In

Figure I.1

TECHNOLOGY OPTIONS FOR MUNICIPAL SOLID WASTE MANAGEMENT



NOTES: 1. APC = Air pollution control
2. Each block indicates a process function, not necessarily a facility.

some communities, however, the tipping fee is levied as a tax on all residents; in others, it includes a profit for the operators. Thus, tipping fees need not be directly correlated with costs.

To standardize the presentation of costs, all costs listed in Tables I.1 through I.9, presented at the end of this exhibit, have been updated to a mid-1991 time frame by using SRI International's PEP Cost Index. This index, which measures the cost trends for process plants, is constructed and maintained by SRI's Process Economics Program (PEP). Graphs of the index are shown in Figure I.2. The base year of the index is mid-1958, which was assigned an index of 100; the mid-1991 index was 540.

The PEP Cost Index is in essence a price inflation index. It reflects neither changes in costs due to changes in process technology nor changes due to such factors as environmental and safety regulations, alternative sources of fuel, and so on. The factors derived from the Index represent averages and may not be representative in any given case.

In addition to the cost index adjustment, all of the capital and the O&M costs in all cost tables have been converted to two common formats. For all cost estimates except those shown in Table I.2, the total capital cost (in millions of dollars) and the unit capacity cost (in thousands of dollars per ton per day) refer to the design capacity of the MSW input to the system. The accompanying O&M cost (in dollars per ton) represents the cost per ton of *MSW actually processed*. Furthermore, the O&M costs are tabulated in two ways: debt service included and debt service excluded.

For the process modules in Table I.2, the unit costs are shown in dollars per ton of the *feed material to the individual process modules*. The accompanying O&M costs in the table represent the cost per ton of material actually processed in the process modules. As in other cost tables, the O&M costs are listed with debt service charge included and excluded.

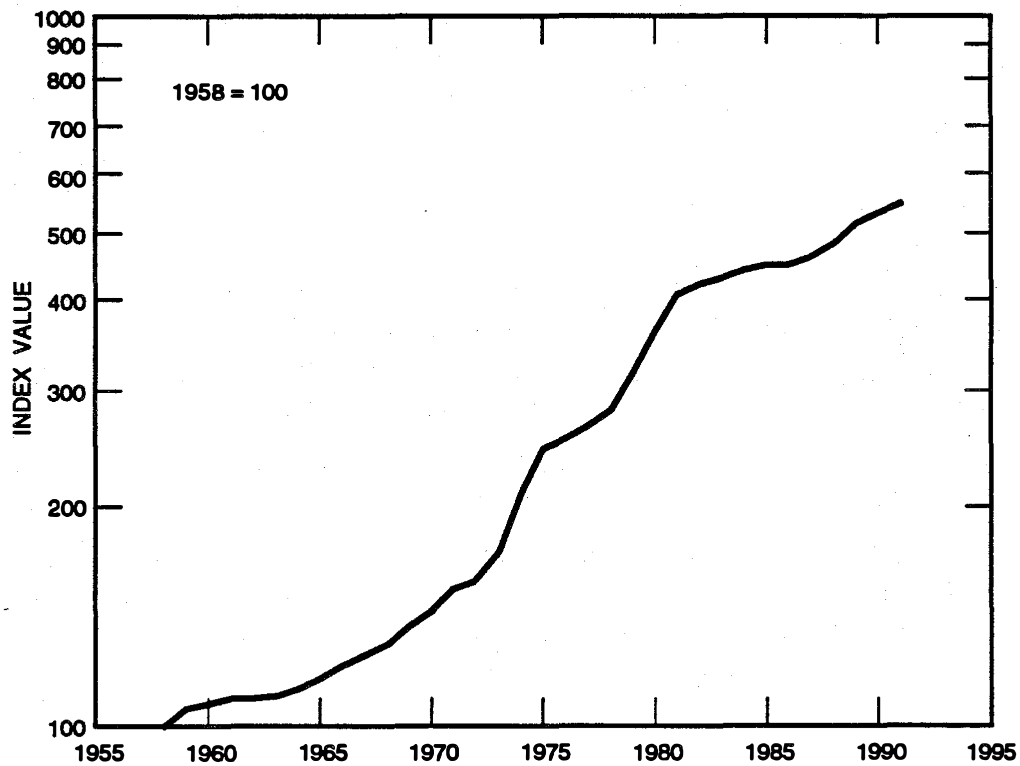
For processes in which electricity is generated as a by-product, it is uniformly priced at $0.035 per kilowatt-hour (3.5¢/kWh) for all process technologies.

Among the processes analyzed in this report, the most extensive data are available for the mass burn, RDF, and composting technologies. In addition to the representative system costs shown in Table I.1 and the process module costs shown in Table I.2, data on mass burn, RDF, and composting are summarized in four additional tables:

Table No.	Content
I.1	Summary of capital and O&M costs for principal technologies
I.2	Summary of capital and O&M costs for process modules (equipment oriented)
I.3	Comparison of landfill capital cost estimates
I.4	Cost data for mass burn plants, modular design
I.5	Cost data for mass burn plants, field erected
I.6	Cost data for RDF plants firing RDF only or cofiring RDF with coal
I.7	Comparison of capital costs for combustion processes
I.8	Cost data for composting plants
I.9	Cost data for material recovery/recycling facilities (MRFs)

Figure I.2

PEP CONSTRUCTION COST INDEX FOR THE UNITED STATES, 1958-1991



Source: SRI International.

We have included the costs for those units that are in advanced planning stages or are under construction. The status of these units, as reported by the Government Advisory Associates (GAA) in 1991, are properly identified in the cost tables and graphs. They are included because these costs seem to be just as informative as the historical costs to planners and budget estimators of MSW technologies.

When sufficient data points are available for individual technologies, the effects of plant capacity on capital and O&M costs are graphically correlated and shown in Figures I.4 to I.24. Note that the O&M costs in the correlations do not include debt service.

System Costs

Table I.1 summarizes the representative capital and operating costs for seven groups of MSW management systems. All of these system costs include the front-end and back-end processing costs (e.g., waste segregation and residue disposal costs are all included). Given the many uncertainties regarding these costs, such as site-specific conditions, financing plans, etc., it is not prudent to draw any definitive conclusions from these costs except for the following observations:

1. The capital investment for landfill is significantly affected by the site-specific conditions. For example, the capital cost of a deep rocky site in Kentucky can be more than three times higher than the capital cost of a shallow rocky site in Michigan.
2. In general, the landfill O&M costs are lower than those of other MSW management technologies.
3. Combustion processes (mass burn and RDF systems) with electricity generation require the highest capital and O&M costs, but they generate by-product credits ranging from $13.44 to $57.09 per ton of MSW processed.
4. Of the three options for using RDF, the fluidized bed combustion and cofiring with coal in a conventional boiler offer lower capital and operating costs than the costs of a stand-alone RDF plus electricity generation system.
5. Tipping fees vary widely, from $14.84 to over $100 per ton of MSW. This broad range primarily reflects differences in the cost allocation methods used for the facilities and other charges, rather than technology differences.
6. The cost data in Table I.1 are not complete in all aspects for each technology. Published data are not available for all of the data points listed.

Process Module Costs

Table I.2 summarizes the capital and O&M costs for stand-alone process modules. The module capacity is based on the feed material in tons per day, except for the landfill gas collection capacity and the unit capacity capital costs. These module capacities and unit capacity capital costs are rated in megawatts (MW) of electricity that can be generated from the collected gas and in dollars per megawatt ($/MW) of generating capacity, respectively.

Similarly, the O&M costs listed in the table are in dollars per ton ($/ton) of the feedstock processed in all cases except the gas collection module; for that module, the O&M costs and the estimated by-product values are expressed as dollars per thousand kilowatt-hours ($/1,000 kWh) of electricity produced.

Anaerobic Digestion Costs

The largest MSW anaerobic digestion demonstration plant was the Refuse Converted to Methane (RefCoM) project at Pompano Beach, Florida. It was designed to process more than 200 tons per day of MSW. The estimated capital investment supported by public financing for a full-scale 400 ton per day anaerobic digestion plant by the RefCoM technology is $43.77 million (in 1991 dollars), of which 88.5% consists of construction cost and the remainder is interest on construction loans. The estimated O&M cost is $39.89 per ton of MSW processed. These costs are included in Tables I.1 and I.2.

The distribution of levelized cost by process unit over the life of the plant, including debt service charges, is estimated approximately as follows:

Process Unit	% of O&M
RDF plant	27.4
Anaerobic digestion	16.2
Gas cleaning	5.0
Residue burning	27.3
Landfill noncombustibles	24.0
Total	100.0

It is thus clear that anaerobic digestion accounts for only 16.2% of the levelized costs, and that major fractions of the cost are for the front-end waste preparation and tail-end residue disposal and product gas clean-up operations.

Landfill Costs

The capital investment for a landfill site is normally a progressive expenditure as the area of a landfill site expands. Very few published estimates of landfill capital investment costs on existing sites were found. This exhibit therefore provides the engineering cost estimates for developing three landfill sites, one in Michigan, one in Kentucky, and a generic site in an unspecified location. The capital and O&M costs are summarized in Table I.1 and discussed under System Costs.

Table I.3 compares the capital components for the three plant sites. It shows that the capital costs are significantly affected by the plant site. For example, the rocky site in Kentucky is more difficult to develop and it incurs the highest construction cost. The unit capital costs for the three sites are as follows:

	Unit Capital ($/ton/day)
Michigan	43,000
Kentucky	134,550
Generic	58,750

Figure 6.4 in Volume I summarizes the unit capital cost distribution and O & M costs for the three plant sites.

Published landfill O&M costs for 1991 by state are shown on a U.S. map in Figure I.3. The New England, Great Lakes, and Atlantic and Pacific coastal states have the highest landfill operating costs. The Plains states and the South have the lowest. The state of New Jersey has the highest costs, ranging from $51 to $154/ton. By contrast, South Dakota has the lowest costs at $3 to $5/ton. The higher cost states largely result from the scarcity of suitable landfill sites, dense population concentration in metropolitan areas, tighter state environmental regulations, and higher transportation and labor costs.

Mass Burn Costs—Modular Design Units

Table I.3 summarizes the published data on the economics of mass burn plants of modular construction. The plants are segregated into three groups. The first group is composed of 34 plants that produce only steam, the second of 4 plants that generate only electricity, and the third of 7 plants that produce both steam and electricity for sale. Each plant consists of one to four modules , and the individual modules vary in capacity from 13 to 150 tons per day of MSW. The largest plant has a total capacity of 13–600 tons per day and consists of four modules.

For the steam production only group of plants, the MSW capacity ranges from 13 to 360 tons per day; the average capacity is 104 tons per day. The unit capital cost ranges from $17,230 to $170,000 per ton of MSW capacity per day; the average unit capital is $63,820 per ton of MSW capacity per day. The O&M cost, excluding debt service charges, ranges from $8.23 to $75.09 per ton of MSW processed; the average is $33.03 per ton of MSW processed. Including debt service charges, the average O&M cost is $55.16 per ton of MSW processed.

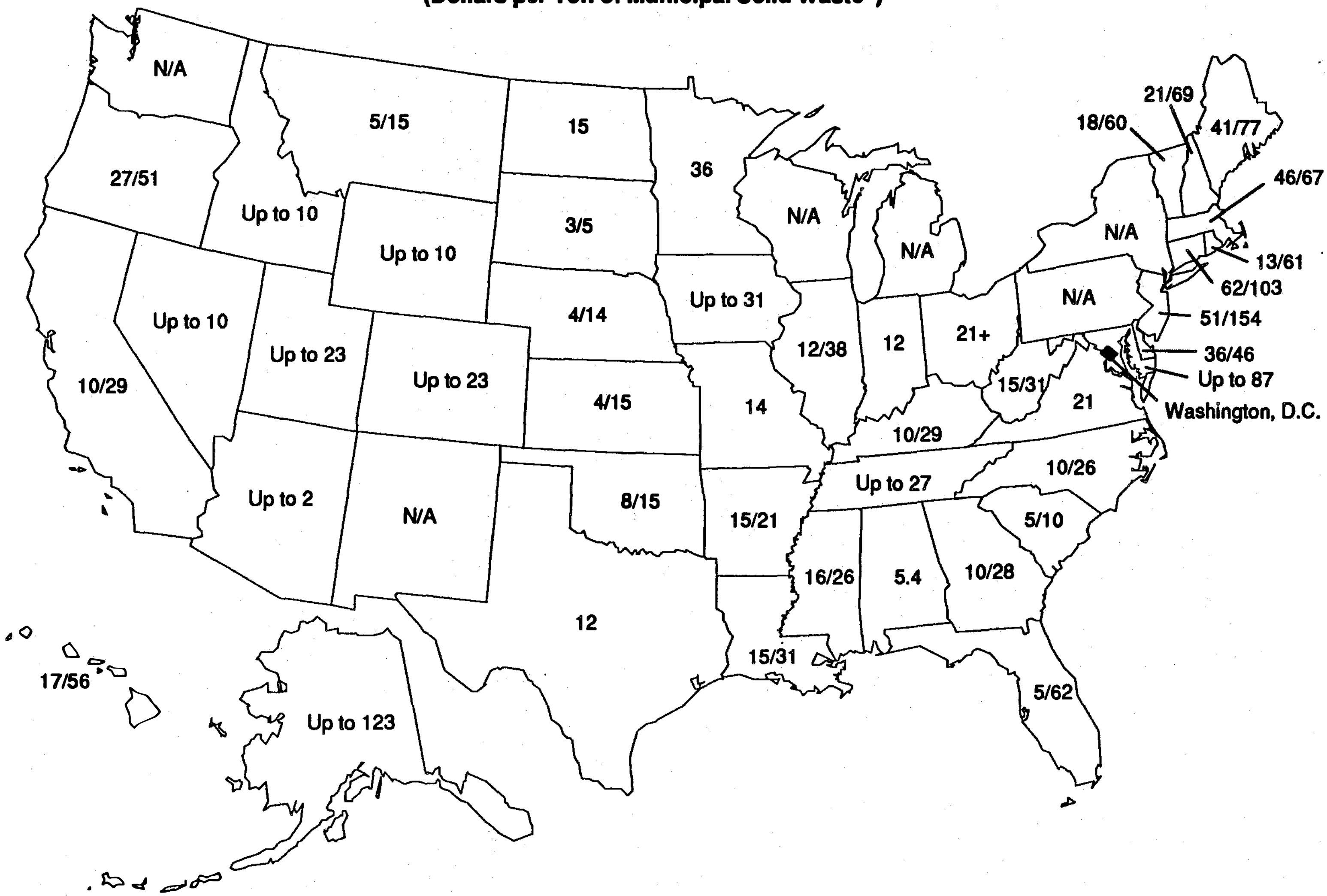
For the electricity production only group of plants, the MSW capacity ranges from 100 to 560 tons per day; the average capacity is 216 tons per day. The unit capital cost ranges from $54,870 to $187,610 per ton of MSW capacity per day; the average unit capital is $107,800 per ton of MSW capacity per day. The O&M cost, excluding debt service charges, ranges from $27.77 to $39.00 per ton of MSW processed; the average is $34.26 per ton of MSW processed. Including debt service charges, the average O&M cost is $47.25 per ton of MSW processed.

For the steam/electricity production plants, the MSW capacity ranges from 80 to 600 tons per day; the average capacity is 224 tons per day. The unit capital cost ranges from $68,330 to $421,000 per ton of MSW capacity per day; the average unit capital is $126,550 per ton of MSW capacity per day. The O&M cost, excluding debt service charges, ranges from $23.66 to $70.97 per ton of MSW processed; the average is $36.71 per ton of MSW processed. Including debt service charges, the average O&M cost is $68.48 per ton of MSW processed.

These costs show that as the plant increases in complexity from marketing only steam to marketing both steam and electricity, the unit capital cost increases, but the O&M costs excluding capital charges remain about the same.

Figure I.3

RANGE OF 1991 U.S. LANDFILL TIPPING FEES BY STATE
(Dollars per Ton of Municipal Solid Waste[a])



[a] Adjusted from 1990 fees to 1991 index.
Note: N/A = data not available.
Source: Glenn and Riggle, 1991.

The average costs for the three groups of plants are shown in the tabulation below. The O&M cost estimates exclude capital charges.

	Steam Plants	Electricity Plants	Steam/Electricity Plants
No. of plants	34	4	7
Average capacity (ton/day)	104	231	243
Average unit capital cost ($/ton/day)	$62,880	$88,500	$95,090
Average O&M cost ($/ton)	$33.29	$33.39	$3171

The effect of plant capacity on capital and O&M costs (excluding debt service charges) for the three groups of mass burn, modular design plants are correlated in the figures listed below, which are provided at the end of this exhibit:

	Figure Number for	
	Capital Cost	O&M Cost
Modular steam only plants	I.4	I.5
Modular electricity only plants	I.6	None
Modular steam/electricity plants	I.7	I.8

No graph is provided for the plant capacity and O&M cost correlation for the electricity only plants because the number of available data points (three) is too small to provide a meaningful correlation.

As shown by the cost correlations, the data points are quite scattered. However, as expected, the statistically derived capital cost curves point upward as the plant increases in capacity, while the O&M cost curve points downward with increasing plant capacity.

Table I.3 also shows the variations in tipping fees. For plants that produce only steam, the tipping fee ranges from $3.09 per ton to as much as $56.57 per ton; the average is $25.13 per ton. For plants that produce electricity, the average tipping fee $67.51. The average tipping fee for the steam/electricity producing group of plants is $49.79 per ton.

Mass Burn Costs—Field Erected Units

Table I.4 summarizes the capital and O&M costs for mass burn systems that are field erected. The total number of plants on the list is 98, of which 10 market only steam, 68 market only electricity, and the remaining 20 market both steam and electricity. The range and average costs for the respective groups of plants are compared as follows:

The comparison shows that both the unit capital and O&M costs for each plant group vary over a broad range. For example, for the electricity production only plants, the unit capital costs range from $30,500 to $201,500 per ton per day, or a high/low ratio of 6.6. For the other two groups of plants, the high/low ratios are about 5. On the average, the unit capital investments for the electricity plants and steam/electricity plants are about 16 to 18% higher than those of the steam only plants.

	Steam Plants	Electricity Plants	Steam/Electricity Plants
No. of plants	10	68	$20
Range of unit capital cost ($1,000/ton/day)	$41.3–209.0	$30.5–210.5	$19.7–206.9
Average unit capital cost ($1,000/ton/day)	$89.41	$105.98	$109.24
Range of O&M cost, No debt service ($/ton)	$11.31–71.0	$9.3 -48.5	$9.3–48.3
Average O&M cost ($/ton)	$29.59	$24.38	$26.50
Average tipping fee ($/ton)	$24.42	$55.90	$49.49

In the ranges of O&M costs (excluding debt service charges), the high/low ratios for the electricity and steam/electricity plant groups are somewhat lower than those of the unit capital costs, at about 5.2, but for the steam only plant group, the high/low ratio is 6.3. Fortuitously, however, the average O&M costs are within a narrow spread of $27 to $28 per ton of MSW processed. On the other hand, the average tipping fees for the electricity and steam/electricity groups of plants are about twice those of the steam only plants.

The effect of plant capacity on capital and O&M costs (excluding debt service charges) for the three groups of mass burn, field-erected plants are correlated in the graphs listed below, which appear at the end of this exhibit:

	Figure Number for	
	Capital Cost	O&M Cost
Field-erected steam only plants	I.9	I.10
Field-erected electricity only plants	I.11	I.12
Field-erected steam/electricity plants	I.13	I.14

No graph is provided for the plant capacity and O&M cost correlation for the electricity-only plants because the number of available data points (two) is too small to provide a meaningful correlation.

Like the cost correlations for the mass burn, modular designed plants, the data points for the field-erected plants are quite scattered. However, the statistically derived capital cost curves point upward as the plant increases in capacity, and the O&M cost curve points downward with increasing plant capacity.

Refuse-Derived Fuel Costs

Table I.5 summarizes the capital and O&M costs for RDF-fired energy recovery systems. The costs are segregated into three groups:

- RDF-stoker-fired plants including boiler investment costs
- RDF-stoker fired plants excluding boiler costs
- RDF cofired with pulverized coal.

The costs for the stoker-fired boilers are compared as follows:

	Including Boiler Cost	Excluding Boiler Cost
Range of unit capital cost ($1,000/ton/day)	49.4–$152.62	11.2–73.9
Average unit capital cost ($1,000/ton/day)	98.36	38.11
Range of O&M costs ($/ton)	13.40–66.90	13.40–30.90
Average O&M cost ($/ton)	36.01	23.14
Average ash disposal fee ($/ton)	30.51	8.23

As might be expected, the inclusion of boiler costs in the plant investment increases both the O&M costs and the tipping fees. Cost correlations showing the effect of plant capacity on costs for these two groups of plants are shown in the figures listed below, which appear at the end of this exhibit:

	Figure Number for	
	Capital Cost	O&M Cost
Boiler cost included	I.15	I.16
Boiler cost excluded	I.17	I.18

The costs for RDF cofired with coal are estimates developed by by the Electric Research Institute (EPRI). For these data, it was assumed that the amount of RDF used for each case was equal to 15% of the energy input to a boiler that is cofired with a U.S. eastern coal. The estimates were made for three capacity cases, each containing two equal-size boilers with 50 (retrofit case), 200, and 500 MW of generating capacity. The capital costs and O&M costs shown for these units are incremental costs over and above the costs of 100% coal-fired boilers. O&M credits shown in Table I.5 for these estimated projects are equivalent savings in fuel costs that are converted to the equivalent of dollars per ton of MSW processed. In terms of electricity cost, the savings amount to about 1 mill/kWh of electricity produced. That savings is equivalent to the breakeven price that a power plant can afford to pay for the RDF—i.e., about $6–$7 per ton on an MSW basis, or about $11.30–$13.20 per ton on an RDF basis.

Comparison of Capital Costs of Combustion Processes

Table I.7 presents a comparison of capital costs for combustion processes published by Waste Age in November 1990. Because the costs in the table are in current dollars, it is not surprising that within each technological group, the average capital investment increases with the time period. For example, in the modular combustor category, for the plants came on stream or are expected to come on stream in the 1983–1993 period, the average unit capital cost is $72,300 per ton per day; that is about twice the investment for the plants that came on stream in the 1975–1982 period, which averaged $35,900 per ton per day. The higher cost for the more recent period reflects both inflation and more stringent environmental control requirements.

Composting Costs

Table I.6 summarizes the capital investments and O&M costs for 16 currently known MSW composting plants in the United States. These plants range in capacity from 10 to 1,000 tons per day of MSW. The corresponding investments range from $0.42 million to $73.54 million; the unit capacity investment ranges from $21,600 to $73,540 per ton of MSW per day. The O&M costs also vary substantially, ranging from $2.35 to $176.37 per ton of MSW processed; the average O&M cost is $66 per ton. The tipping fee varies from $15.43 to $78.12 per ton. In two of the communities, in lieu of a tipping fee, a monthly service tax is levied on each household.

The effects of plant capacity on the plant investment and O&M costs are shown in Figures I.19 and I.20, respectively.

Material Recovery Facilities

Table I.9 summarizes the capital and O&M costs for MRFs. The plants are subdivided into two groups—low-tech (11) and high-tech (14)—according to degree of mechanization. As might be expected, the average capital cost of high-tech plants ($37,000 per ton per day) is higher than that of the low-tech plants ($27,000 per ton per day). On the other hand, the average O&M cost is higher for the low-tech plants ($65 per ton) than for the high-tech plants because of higher labor costs.

An oddity appears when O&M costs including and excluding debt service charges are compared. For both high-tech and low-tech plants, the average O&M costs excluding debt service charges in Table I.9 are higher than the corresponding average O&M costs including debt service charges. The discrepancy is caused by the scarcity of data points for the O&M costs including debt service charges.

The effects of plant capacity on capital and O&M costs for the two groups of MRFs are shown in the following figures:

	Figure Number for	
	Low-Tech	**High-Tech**
Capital cost	I.21	I.22
O&M cost (excluding debt sevice charges)	I.23	I.24

WAYS TO IMPROVE THE COMPARABILITY OF THE COST ESTIMATES

The tables and figures that follow present published capital and operating costs of MSW management technologies that have been updated and converted to an equivalent form to permit users to compare the economics of the various technical approaches. However, because the existing data are incomplete and inconsistent, they can serve only as preliminary guides for decision making, not as tools for future project planning. The inconsistencies in the data result from variations in site-specific conditions, equipment specifications, performance standards, location factors, and methods of cost accumulation and allocation In some of the reported projects, improvements and retrofits were made after plant start-up, and the capital expenditures spanned a period of many years. Because no annual cash flow data are available for any of these projects, the economics of the projects cannot be compared on a discounted cash flow or present value basis. To develop a sound cost data base for future economic analyses, it will be necessary to standardize the cost accumulation and reporting procedures on a nationwide basis.

More reliable economic comparisons of different technologies could be developed if, instead of using historical data that are full of uncertainties, the system requirements were uniformly defined for each technology, and the capital costs of each technology were built up from the costs of individual process modules developed from vendors' quotations. For each process module or process auxiliary, the costs would be accumulated for a range of capacities, and the effect of significant process variables on costs would be correlated. These process module costs permit the development of system costs for the process variations that might be required by a given set of environmental constraints. In addition, location factors would be developed for different parts of the country so that the costs developed for one area can be translated into the costs of other areas.

In a similar way, the O&M cost of an MSW management technology can be built up from its cost components, such as materials, utilities, operating and maintenance labor, plant overheads, and capital charges. The key point is to set uniform standards for cost development and application for all technologies

Table I.1

SUMMARY OF REPRESENTATIVE CAPITAL AND OPERATING COSTS OF MAJOR SOLID WASTE MANAGEMENT SYSTEMS

ALL COSTS NORMALIZED TO 1991 COST INDEX

Technology	MSW Capacity (Tons/day)	Capital Cost ($1,000/ton/day)	O & M Cost Excluding Capital Charges ($/ton)	O & M Cost Including Capital Charges ($/ton)	Estimated By-product Value ($/ton)	Tipping Fee ($/ton)	Reference
Anaerobic Digestion							
Refuse Conversion to Methane (RefCoM) Project, IL^	400	109.42	N/A	39.89	1.78	40	Appendix H
Composting							
With Windrow^	18-350	46.3-30.1	45.4-N/A	N/A	N/A	30-26	Appendix G
Other technologies^	16-1,350	75.5-40.4	13-16.89	N/A	N/A	0-45	Appendix G
Landfill							
A site in Kentucky	750	134.55*	16.07	N/A	N/A	N/A	Appendix F
A site in Michigan	1,000	43.20**	11.69	N/A	N/A	N/A	Appendix F
A generic site	1,250	58.75	N/A	N/A	N/A	N/A	Appendix F
Mass Burn + Electricity Production							
Bellingham, WA	100	104.76	N/A	N/A	N/A	110.33	Appendix A
Eau Claire County, WI	150	96.49	39.00	45.00	N/A	N/A	Appendix A
Key West	150	93.48	36.00	61.71	N/A	205.71	Appendix A
Long Beach, NY	200	119.54	N/A	N/A	N/A	N/A	Appendix A
City of Commerce, CA	300	202.2	N/A	N/A	22.40	14.84	CEC, 1991
Will County, IL	550	114.9	30.59	N/A	16.00	49.34	Patrick Eng., 1991
Pinellas, FL^	2,000	120.0	37.81	52.19	15.50	26.28	Appendix A
RDF + Electricity Production							
Penobscot Energy Recovery, ME	750	101.71	66.86	N/A	N/A	N/A	Appendix B, Sect. B4
Akron Recycle Energy Rec, OH	1,000	107.35	54.51	59.66	N/A	N/A	Appendix B, Sect. B4
Columbus S.W. Reduction, OH^	2,000	121.95	42.17	74.06	N/A	N/A	Appendix B, Sect. B4
Greater Detroit Resource Rec., MI	4,000	94.42	N/A	N/A	N/A	N/A	Appendix B, Sect. B4
RDF Co-fired with Coal + Electricity Production^							
Columbus, Ohio	2,000	86.00^^	N/A	N/A	16.80	N/A	CEC, 1991
Norfolk Naval Ship Yard	2,000	93.00^^	N/A	N/A	13.44	N/A	CEC, 1991
RDF Burned in Fluidized Bed + Elctricity production							
Northern State Power, La Crosse WI	412	71.63	N/A	N/A	57.09	44.9	Appendix C
Duluth, MN	930	27.96	N/A	N/A	N/A	N/A	Appendix C
Tacoma, WA	1,000	51.95	N/A	N/A	42.00	N/A	Appendix C

Notes: ^ Engineering estimate. ^^ Incremental to the coal-fired plant costs. * A deep rocky site. ** A shallow rocky site.

Table I.2

SUMMARY OF REPRESENTATIVE CAPITAL AND OPERATING COSTS OF SOLID WASTE EQUIPMENT-ORIENTED PROCESS MODULES

ALL COSTS NORMALIZED TO 1991 COST INDEX

Process Unit	Module Capacity (Tons/day)	Capital Cost ($1,000/ton/day)	O & M Cost Excluding Capital Charges ($/ton)	O & M Cost Including Capital Charges ($/ton)	Estimated By-product Value ($/ton)	Tipping Feed ($/ton)	Reference
Air Pollution Control (APC) Costs*							
Selective Catalytic Reduction (SCR)	1000	3.72	3.74	N/A	N/A	N/A	Appendix A
Fabric filter (FF) for spray dryer absorber (SDA)	1,050	7.94	2.86	N/A	N/A	N/A	Appendix A
Electron Beam (E-Beam) + FF	N/A	20.36	4.42	N/A	N/A	N/A	Appendix A
Thermal DeNOx	1,000	0.9	1.51	N/A	N/A	N/A	Appendix A
Electrostatic precipitator (ESP) for SD/	350	25.20	8.27	N/A	N/A	N/A	Appendix A
Spray dryer + ESP for field erected	1,050	8.40	2.76	N/A	N/A	N/A	Appendix A
mass burn unit	1,000	N/A	8.46	N/A	N/A	N/A	Appendix A
Spray dryer + ESP for modular mass burn unit	100	N/A	18.12	N/A	N/A	N/A	Appendix A
Spray dryer + ESP for RDF unit	3,000	N/A	9.66	N/A	N/A	N/A	Appendix A
Anaerobic Digestion							
U of FL Sequenced Batch Anaerobic Compositing Process	35	47.02	N/A	41.64	11.00	30.64	Appendix H
Refuse Conversion to Methane* (RefCoM) Process							
RDF plant	100	2.5	N/A	13.61	N/A	N/A	Appendix H
Anaerobic digester	100	N/A	N/A	8.07	N/A	N/A	Appendix H
Gas cleaning	100	N/A	N/A	2.4	N/A	N/A	Appendix H
Residue Incineration	100	N/A	N/A	13.52	N/A	N/A	Appendix H
Landfill of residues	100	N/A	N/A	11.88	N/A	N/A	Appendix H

Total				49.48			
Ash Management Costs							
Brick manufacture	N/A	N/A	45.00	N/A	N/A	N/A	Appendix A
Landfill "as is"	N/A	N/A	14.06	N/A	N/A	N/A	Appendix A
Landfill + 10% cement	N/A	N/A	19.70-30.94	N/A	N/A	N/A	Appendix A
Landfill + excess lime in ash	N/A	N/A	70.31	N/A	N/A	N/A	Appendix A
Landfill + geopolymerization	N/A	N/A	36.56	N/A	N/A	N/A	Appendix A
Vitrification by Penberthy furnace	50	78.75	96.75	N/A	N/A	N/A	Appendix A
Collection Costs in Hudson Valley, N.Y.							
Mixed paper & containers in a 2-compartment vehicle	N/A	N/A	N/A	46.29	N/A	N/A	Appendix E

Table I.2

SUMMARY OF REPRESENTATIVE CAPITAL AND OPERATING COSTS OF SOLID WASTE EQUIPMENT-ORIENTED PROCESS MODULES

ALL COSTS NORMALIZED TO 1991 COST INDEX

Process Unit	Module Capacity (Tons/day)	Capital Cost ($1,000/ton/day)	O & M Cost Excluding Capital Charges ($/ton)	O & M Cost Including Capital Charges ($/ton)	Estimated By-product Value ($/ton)	Tipping Feed ($/ton)	Reference
Same as above including plastics	N/A	N/A	N/A	46.29	N/A	N/A	Appendix E
On route sorting	N/A	N/A	N/A	105.94	N/A	N/A	Appendix E
Same as above including plastics	N/A	N/A	N/A	101.83	N/A	N/A	Appendix E
3-way sorting of newpaper, containers, low grade paper, and organics to composting	N/A	N/A	N/A	49.37	N/A	N/A	Appendix E
Same as above including plastics	N/A	N/A	N/A	47.31	N/A	N/A	Appendix E
Fully sorting of all recyclables and yard waste-2 vehicles	N/A	N/A	N/A	158.4	N/A	N/A	Appendix E
Composting							
Windrow*	400	21.04-41.57	18.18-35.29	N/A	N/A	N/A	Appendix G
In-vessel*	400	13.18-16.55	20.31-28.87	N/A	N/A	N/A	Appendix G
Vendor-designed Facilities							
Wright County, MN	160	92.23	N/A	N/A	N/A	N/A	Appendix G
Scott/Carver	200	72.71	N/A	N/A	N/A	N/A	Appendix G
East Central, MN	250	57.49	N/A	N/A	N/A	N/A	Appendix G
Landfill							
Site characterization*	220	0.89	N/A	N/A	N/A	N/A	Appendix H
Preliminary development*	220	13.18	N/A	N/A	N/A	N/A	Appendix H
Final development costs*							
Clearing and grubbing	220	1.52	N/A	N/A	N/A	N/A	Appendix H
Excavation & stockpile	220	32.64	N/A	N/A	N/A	N/A	Appendix H
Linear & leachate collection	220	108.81	N/A	N/A	N/A	N/A	Appendix H
Leachate management systems	220	216.24	12.67	N/A	N/A	N/A	Appendix H
Gas collection costs							
Olinda, CA	21.3^	575^^	N/A	N/A	35.00	N/A	Appendix H
Puente Hills, CA	158.6^	277.23^^	5.59^	N/A	35.00	N/A	Appendix H
Calumet, IL	26.1^	277.23^^	N/A	N/A	35.00	N/A	Appendix H
Mountain View, CA	5.2^	278.35^^	N/A	N/A	35.00	N/A	Appendix H
Davis Street, CA	15.87^	140.28^^	N/A	N/A	35.00	N/A	Appendix H
Monterey Park, CA	44.64^	249.40^^	N/A	N/A	35.00	N/A	Appendix H
Mass Burn							
Small sizes-no power generation	<250	40-68	N/A	N/A	N/A	N/A	Appendix A
Small to medium-no power	200-500	70-90	N/A	N/A	N/A	N/A	Appendix A

Table I.2

SUMMARY OF REPRESENTATIVE CAPITAL AND OPERATING COSTS OF SOLID WASTE EQUIPMENT-ORIENTED PROCESS MODULES

ALL COSTS NORMALIZED TO 1991 COST INDEX

Process Unit	Module Capacity (Tons/day)	Capital Cost ($1,000/ton/day)	O & M Cost Excluding Capital Charges ($/ton)	O & M Cost Including Capital Charges ($/ton)	Estimated By-product Value ($/ton)	Tipping Feed ($/ton)	Reference
Medium to large-power generation	500-1,500	85-112	N/A	N/A	N/A	N/A	Appendix A
Large with power generation	2,000-3,000	112-129	N/A	N/A	N/A	N/A	Appendix A
Modular combustors	N/A	70-100	20-40	N/A	N/A	N/A	Appendix A
Field-erected mass burn	200	78.17	24.84	N/A	N/A	N/A	Appendix A
Modular combustor	200	42.17	27.12	N/A	N/A	N/A	Appendix A
Pittsfield, MA (modular combustor)	240	52.00	12.32	N/A	N/A	N/A	Appendix A
Material Recovery/Recycling Facilities							
Average of 73 facilities	2-660	1.2-211.8	5.75 - ?	8.63-70.58	N/A	N/A	Appendix E
Average of 28 existing facilities	2-470	1.2-84.7	5.75 - ?	5.75 - ?	N/A	N/A	Appendix E
Average of 45 new facilities	10-660	6.4-211.8	11.72-40.72	31.76-42.35	N/A	N/A	Appendix E
Residue disposal	N/A	N/A	11.65-121.24	N/A	N/A	N/A	Appendix E
Pyrolysis and Gasification							
Dual fluidized bed gasifier, Funabashi City, Japan	450	117.6	27.00	N/A	N/A	N/A	Appendix D
Partial air combustion in a fixed bed reactor, Cretell, France*							
Conceptual plant A	300	88.35	35.20	N/A	N/A	N/A	Appendix D
Conceptual plant B	900	68.65	21.53	N/A	N/A	N/A	Appendix D
Conceptual plant A	1,500	60.39	17.81	N/A	N/A	N/A	Appendix D
Refuse-Derived Fuel (RDF) Module							
Lakeland, FL	200	38.48	12.42	34.28	N/A	15.56	CEC, 1991
Rochester, N.Y.**	2,000	54.90	46.7	N/A	N/A	N/A	CEC, 1991
RDF/Sludge Gasifier Module*							
Biomass Gasification Project	640	22.0	5.72	29.82	16.70	25	CEC, 1991
DOE/Gas Research Institute Study	207.5	58.5	22.43	N/A	6.94	20	CEC, 1991

* Engineering estimate.

** The unit is inactive.

^ Unit is in MW.

^^ Unit is per MW electricity capacity. .

Table I.3

LANDFILL CAPITAL COST ESTIMATES

ALL COSTS NORMALIZED TO 1991 COST INDEX

	Michigan Site (1,000 Tons/Day, MSW)		Kentucky Site (750 Tons/Day, MSW)		Generic Site (1,250 Tons/Day, MSW)	
Cost Component	($Million)	(% of Total)	($Million)	(% of Total)	($Million)	(% of Total)
Predevelopment	7.69	17.8	6.76	6.7	3.08	4.2
Construction	27.09	62.7	78.71	78.0	38.19	52.0
Closure	2.59	6.0	9.89	9.8	17.26	23.5
Post-Closure	5.83	13.5	5.55	5.5	14.91	20.3
Total	43.20	100.0	100.91	100.0	73.44	100.0
($/ton/day)	43,200		134,550		58,750	

Reference: Appendix F, wTe.

Table I.4

CAPITAL AND OPERATING COSTS OF MODULAR MASS BURN SYSTEMS

ALL COSTS NORMALIZED TO 1991 COST INDEX

Project Name	State	No. of Modules	Design Capacity (Tons/day)	Total Investment ($ Million)	Unit Capital Cost ($1,000/ton/day)	O & M Cost Excluding Debt Service Charges ($/ton)	O & M Cost ncluding Debt Service Charges ($/ton)	Tipping Feed ($/ton)
Steam Only Plants								
Gatesville, Dept. of Correctior	TX	1	13	0.77	59.34	N/A	N/A	N/A
Beto 1, TX Dept. of Correction	TX	1	25	1.54	61.71	N/A	N/A	N/A
Center	TX	1	40	2.16	54.00	28.67	50.26	5.14
City of Carthage	TX	1	40	2.40	60.00	36.03	42.67	N/A
Cassia County	ID	1	50	1.75	35.05	28.80	N/A	N/A
Collegeville	MN	1	50	3.44	68.88	8.23	N/A	N/A
Lewis County	TN	1	50	1.80	36.00	N/A	N/A	N/A
Mayport Naval Station	FL	1	50	3.52	70.44	75.09	N/A	N/A
Osceola	AR	1	50	1.72	34.44	27.53	N/A	N/A
Westmoreland County	PA	2	50	5.16	103.20	50.71	N/A	3.09
Waxahachie	TX	N/A	50	2.92	58.44	31.89	49.37	N/A
Richard Asphalt	MN	N/A	57	5.21	72.41	37.03	49.37	N/A
Miami International Airport	FL	1	60	5.01	83.46	11.31	N/A	N/A
Red Wing	MN	N/A	72	4.47	62.07	38.06	58.63	N/A
Fort Leonard Wood	MO	1	75	4.38	58.44	19.54	N/A	N/A
Park County	MT	1	75	3.63	48.41	18.00	46.59	N/A
Fort Dix	NJ	4	80	7.80	97.50	47.80	N/A	N/A
Pope-Douglas	MN	2	80	6.96	87.00	74.28	106.97	51.43
Polk County	MN	3	80	9.00	112.50	45.71	70.77	56.57
Fergus Falls	MN	2	94	4.92	52.34	50.73	65.76	35.49
Batesville	AR	1	100	1.72	17.23	15.43	N/A	N/A
Dyersburg	TN	1	100	2.87	28.70	28.80	39.09	N/A
Salem	VA	N/A	100	3.67	36.70	33.00	40.00	N/A
Lamprey Regional SW Co-op	NH	1	108	4.74	43.85	48.34	74.06	N/A
Miami	FL	1	108	3.93	36.40	20.57	N/A	N/A
Cattaraugus County	NY	1	112	6.26	55.93	32.91	38.06	N/A
Perham	MN	1	116	8.16	70.34	N/A	N/A	27.77
Fort Lewis**	WA	3	120	20.40	170.00	N/A	N/A	N/A
Pascagoula	MS	2	150	8.28	55.20	27.80	41.70	17.93
Elk River Resource Recovery*	TN	2	200	17.40	87.00	27.87	N/A	3.09
Pittsfield	MA	N/A	240	14.35	59.77	37.03	55.54	N/A
Hampton	SC	2	270	12.00	44.44	N/A	N/A	25.71
Tuscaloosa Energy Recovery	AL	N/A	300	11.65	38.83	13.37	N/A	N/A
Harnford County	MD	3	360	28.01	77.80	17.52	34.84	N/A
Average			**104**	**6.53**	**62.88**	**33.29**	**53.98**	**25.13**

Table I.4

CAPITAL AND OPERATING COSTS OF MODULAR MASS BURN SYSTEMS

ALL COSTS NORMALIZED TO 1991 COST INDEX

Project Name	State	No. of Modules	Design Capacity (Tons/day)	Total Investment ($ Million)	Unit Capital Cost ($1,000/ton/day)	O & M Cost Excluding Debt Service Charges ($/ton)	O & M Cost ncluding Debt Service Charges ($/ton)	Tipping Feed ($/ton)
Electricity Only Plants								
Bellingham	WA	1	100	10.48	104.76	N/A	N/A	110.33
Cleburne	TX	3	115	6.31	54.87	27.77	65.83	24.69
Eau Claire County*	WI	N/A	150	14.47	96.49	39.00	45.00	N/A
Manchester*	NH	N/A	560	54.81	97.87	N/A	16.46	N/A
Average			**231**	**21.52**	**88.50**	**33.39**	**42.43**	**67.51**
Steam and Electricity Plants								
Barron County	WI	2	80	6.72	84.00	34.97	58.63	27.77
Windham	CT	N/A	108	11.16	103.36	42.17	72.00	N/A
St. Croix County	WI	3	115	10.02	87.16	23.66	48.34	60.39
Muskegon County*	MI	N/A	180	12.30	68.33	24.69	42.17	48.34
Oswego County	NY	4	200	16.27	81.33	28.57	47.14	N/A
Wallingford	CT	3	420	43.85	104.40	44.23	68.91	50.40
Pigeon Point	DE	4	600	82.21	137.02	23.66	54.51	62.04
Average			**243**	**26.08**	**95.09**	**31.71**	**55.96**	**49.79**

* Advanced planning.
**Under construction.

General note: The project status for individual plant is as of 1990 reported by Government Advisory Associates in 1991.

Source: Reference 7.

Table I.5

CAPITAL AND OPERATING COSTS OF FIELD-ERECTED MASS BURN SYSTEMS

ALL COSTS NORMALIZED TO 1991 COST INDEX

Project Name	State	Design Capacity (Tons/day)	Total Investment ($ Million)	Unit Capital Cost ($1,000/ton/day)	O & M Cost Excluding Capital Charges ($/ton)	O & M Cost Including Capital Charges ($/ton)	Tipping Feed ($/ton)
Steam Only Plants							
Sitka^	AK	24	5.02	209.03	70.97	N/A	4.11
Galax	VA	56	2.58	46.08	49.37	69.94	N/A
City of Waukesha	WI	175	10.97	62.67	14.40	47.31	N/A
Hampton/NASA Project Recoup	VA	200	19.99	99.95	34.97	45.26	N/A
Norfolk Naval Station	VA	360	19.29	53.57	33.98	N/A	N/A
Davis County	UT	400	52.98	132.44	15.03	51.64	55.67
Savannah	GA	500	40.15	80.30	11.31	33.94	18.51
Huntsville^	AL	690	74.57	108.07	30.86	85.37	25.30
Betts Avenue	NY	1,000	60.72	60.72	23.66	N/A	N/A
Indianpolis Resource Recovery^	IN	2,362	97.51	41.28	11.31	23.66	18.51
Average		**577**	**38.38**	**89.41**	**29.59**	**51.02**	**24.42**
Electricity Only Plants							
Skagit County	WA	178	15.35	86.22	28.80	45.26	48.34
Auburn (new plant)	ME	200	27.26	136.29	23.66	72.00	85.00
New Hampshire/Vermont	NH	200	30.40	152.00	38.06	55.54	77.14
Montgomery County (North)	OH	300	37.06	123.52	23.66	27.77	17.49
City of Commerce	CA	400	39.27	98.18	46.29	97.71	26.74
Warren county	NJ	400	53.07	132.67	28.80	38.06	98.00
Washington/Warren Counties**	NY	400	51.43	128.57	38.06	87.43	77.14
Gaston County	NC	440	44.31	100.71	N/A	N/A	N/A
Camden County (Pennsauken)**	NJ	500	90.51	181.03	23.66	N/A	N/A
Glendon*	PA	500	65.31	130.63	N/A	N/A	N/A
Lisbon*	FL	500	102.86	205.71	N/A	N/A	N/A
Portland	ME	500	71.06	142.13	21.60	68.91	46.29
Concord Regional S.W. Recv.	NH	500	61.37	122.75	N/A	N/A	37.44
Bay Resource Mgt. Center	FL	510	42.63	83.58	19.54	54.51	30.86
MacArtur Enegy Recovery	NY	518	44.40	85.71	27.77	N/A	41.14
Lake County	FL	528	61.71	116.88	28.80	63.77	41.14
Eastern Central Project*	CT	550	82.30	149.63	28.53	N/A	N/A
Marion County Solid Waste	OR	550	53.28	96.88	20.57	49.37	56.57
Glouchester	NJ	575	61.71	107.33	N/A	N/A	89.49
Preston (S.E. CT)**	CT	600	90.98	151.64	37.03	74.06	61.71
Charleston County	SC	644	62.47	97.00	20.57	56.32	25.71
Bristol	CT	650	67.45	103.78	26.74	63.77	44.23
Babylon Resource Recovery	NY	750	102.60	136.80	48.49	81.79	80.23

Table I.5

CAPITAL AND OPERATING COSTS OF FIELD-ERECTED MASS BURN SYSTEMS

ALL COSTS NORMALIZED TO 1991 COST INDEX

Project Name	State	Design Capacity (Tons/day)	Total Investment ($ Million)	Unit Capital Cost ($1,000/ton/day)	O & M Cost Excluding Capital Charges ($/ton)	O & M Cost Including Capital Charges ($/ton)	Tipping Feed ($/ton)
Huntington**	NY	750	157.89	210.51	39.09	103.89	102.86
Johnston (Central Landfill)*	RI	750	82.29	109.71	48.34	92.57	N/A
Dakota County*	MN	800	111.96	139.95	28.80	82.29	N/A
Stanislaus County Resource	CA	800	94.30	117.87	22.63	47.31	22.00
Spokane	WA	800	90.05	112.56	23.66	57.60	55.00
Montgomery County (South)*	OH	900	27.42	30.47	33.94	40.11	N/A
Alexandria/Arlington RR	VA	975	89.18	91.47	N/A	N/A	39.09
Mercy County*	NJ	975	125.97	129.20	30.86	64.80	N/A
McKay Bay Refuse	FL	1,000	83.95	83.95	18.51	62.74	66.86
Oyster Bay*	NY	1,000	138.86	138.86	N/A	N/A	N/A
San Juan Resource Recovery*	PR	1,040	96.43	92.72	17.49	41.14	N/A
Pasco County**	FL	1,050	95.59	91.04	16.46	54.51	39.56
Camden Conty (Foster Wheeler)**	PA	1,050	105.23	100.22	39.09	N/A	90.51
Hillsborough County	FL	1,200	88.24	73.53	16.46	N/A	N/A
Hennepin	MN	1,200	85.77	71.47	33.94	73.03	97.71
Lancaster county**	PA	1,200	107.62	89.68	19.54	N/A	53.49
Montgomery County**	PA	1,200	121.33	101.11	13.37	N/A	N/A
Morris County*	NJ	1,340	149.71	111.73	16.46	N/A	N/A
York County	PA	1,344	97.78	72.75	9.26	45.26	39.86
S.E. Resource Recovery	CA	1,380	116.19	84.20	18.51	55.54	17.49
Passaic County*	NJ	1,434	146.06	101.85	N/A	N/A	N/A
Union county*	NJ	1,440	154.29	107.14	31.89	79.20	N/A
Albany (American Ref-Fuel)	NY	1,500	211.01	140.68	N/A	N/A	N/A
East Bridgeport (Am Ref-Fuel)*	CT	1,500	178.02	118.68	N/A	N/A	N/A
Hudson County*	NJ	1,500	188.86	125.90	18.51	N/A	N/A
North Andover	MA	1,500	212.23	141.49	12.34	63.77	62.74
Central MA Res. Recovery	MA	1,500	157.05	104.70	39.09	67.89	46.29
Saugas	MA	1,500	173.99	116.00	39.09	N/A	N/A
West Pottsgrove Recycling*	PA	1,500	154.29	102.86	N/A	N/A	N/A
Haverhill (Mass Burn)	MA	1,650	131.54	79.72	N/A	N/A	77.14
Monmouth County*	NJ	1,700	226.29	133.11	N/A	N/A	N/A
Lee County*	FL	1,800	151.16	83.98	N/A	N/A	N/A
Montgomery County*	PA	1,800	295.42	164.12	N/A	N/A	N/A
Oakland county*	MI	2,000	176.91	88.46	N/A	N/A	N/A
Bridgeport RESCO	CT	2,250	253.20	112.53	23.66	56.57	44.74
Broward County S. Facility**	FL	2,250	285.75	127.00	22.63	58.63	64.29
Broward County N. Facility**	FL	2,250	222.18	98.75	29.83	62.74	63.77

Table I.5

CAPITAL AND OPERATING COSTS OF FIELD-ERECTED MASS BURN SYSTEMS

ALL COSTS NORMALIZED TO 1991 COST INDEX

Project Name	State	Design Capacity (Tons/day)	Total Investment ($ Million)	Unit Capital Cost ($1,000/ton/day)	O & M Cost Excluding Capital Charges ($/ton)	O & M Cost Including Capital Charges ($/ton)	Tipping Feed ($/ton)
Falls Township(Wheelerbrator)*	PA	2,250	205.71	91.43	N/A	N/A	N/A
Westchester	NY	2,250	209.14	92.95	N/A	N/A	N/A
Essex County**	NJ	2,277	266.40	117.00	17.49	50.40	104.91
Hempstead (America Ref-Fuel)	NY	2,505	292.53	116.78	14.40	44.23	23.04
Delaware County Regional	PA	2,688	283.89	105.61	19.73	44.40	61.71
Bergen County*	NJ	3,000	344.57	114.86	15.43	N/A	N/A
Fairfax County	VA	3,000	209.60	69.87	16.46	37.03	22.53
Pinellas County (Wheelabrator)	FL	3,150	164.28	52.15	14.40	42.17	N/A
Average		**1,204**	**121.10**	**105.98**	**24.38**	**56.29**	**55.90**
Steam and Electricity Plants							
Falls Township*	PA	70	7.20	102.86	N/A	N/A	N/A
Muscoda	WI	125	9.85	78.80	42.71	85.41	32.91
Olmstead County	MN	190	32.89	173.08	43.20	104.91	77.14
S. Michigan State Prison	MI	200	31.41	157.05	48.34	92.57	61.71
Sumner County	TN	200	18.51	92.55	41.14	61.71	N/A
Davidson County**	TN	210	8.31	39.56	N/A	27.77	27.00
University City Resource RR	NC	235	29.60	125.94	20.57	N/A	25.20
Glen Cove^	NY	250	45.48	181.91	20.57	27.77	N/A
Wayne County*	NC	300	27.77	92.57	N/A	N/A	N/A
Sangamon County*	IL	450	39.25	87.22	18.51	40.11	N/A
Monroe County*	ID	500	102.86	205.71	N/A	N/A	N/A
Duchess County	NY	506	43.45	85.87	21.60	56.57	90.51
Waukesha County (New Plant)*	WI	600	124.14	206.90	N/A	N/A	N/A
Kent County	MI	625	65.63	105.00	29.83	63.77	40.11
Quonset Point*	RI	710	85.37	120.24	26.74	97.71	N/A
Harrisburg	PA	720	48.28	67.06	22.63	41.14	N/A
Nashville Thermal Transfer	TN	1,120	98.50	87.95	19.54	29.83	N/A
Walter B. Hall Resource Rec	OK	1,125	22.11	19.65	14.40	42.17	43.20
N.W. Waste-To-Energy Facility	IL	1,600	94.21	58.88	9.26	N/A	N/A
S.W. Resource Recovery	MD	2,250	216.15	96.07	18.51	55.54	47.57
Average		**599**	**57.55**	**109.24**	**26.50**	**59.07**	**49.49**

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^ Sludge codisposal.

*Advanced planning.

Table I.5

CAPITAL AND OPERATING COSTS OF FIELD-ERECTED MASS BURN SYSTEMS

ALL COSTS NORMALIZED TO 1991 COST INDEX

Project Name	State	Design Capacity (Tons/day)	Total Investment ($ Million)	Unit Capital Cost ($1,000/ton/day)	O & M Cost Excluding Capital Charges ($/ton)	O & M Cost Including Capital Charges ($/ton)	Tipping Feed ($/ton)

**Under construction.

General note: The project status of individual plant is of 1990, reported by Government Advisory Associates (GAA) in 1991.

Source: Reference 7.

Table I.6

CAPITAL AND OPERATING COSTS OF RDF-FIRED ENERGY RECOVERY SYSTEMS

ALL COSTS NORMALIZED TO 1991 COST INDEX

Project Name	State	Equivalent MSW Capacity (Tons/day)	Capital Investment ($ Million)	Unit Capital Cost ($1,000/ton/day)	O & M Cost Excluding Debt Service Charges ($/ton)	O & M Cost Including Debt Service Charges ($/ton)	Ash Disposal ($/ton)
RDF Stoker-fired Including Boiler Costs							
Maine Energy Recovery Co.	ME	607	75.16	123.82	N/A	N/A	N/A
Penobscot Energy Recovery Co.	ME	750	76.28	101.71	66.86	N/A	25.71
ANSWERS/Albany Steam	NY	800	39.52	49.40	51.43	N/A	N/A
Lawrence & Haverhill (RDF)	MA	900	137.36	152.62	N/A	N/A	N/A
Akron Recycle Energy Systems	OH	1,000	107.35	107.35	54.51	59.66	N/A
Ramsey & Washington Counties	MN	1,000	53.57	53.57	N/A	N/A	N/A
Anoka County/Elk River R.R. Proj.	MN	1,500	74.54	49.69	16.46	26.74	56.57
SEMASS	MA	1900^	238.62	119.31	31.95	63.05**	14.04
Columbus S.W. Reduction Facility	OH	2,000	243.91	121.95	42.17	74.06	N/A
Mid-Connecticut RDF/MWC	CT	2,000	217.41	108.70	31.89	80.23	25.71
Niagara Falls	NY	2,000	201.13	100.56	N/A	N/A	N/A
Palm Beach County	FL	2,000	194.13	97.07	26.74	89.49	N/A
S.W.Tidewater Energy Project	VA	2,000	175.64	87.82	32.91	38.06	N/A
City & County of Honolulu	HI	2,160	205.71	95.24	27.77	63.77	N/A
Dade County S.W. Resource Recv.	FL	3,000	331.72	110.57	13.37	24.69	N/A
Greater Detroit Resource Recv.	MI	4,000	377.69	94.42	N/A	N/A	N/A
Average		**1,714**	**171.86**	**98.36**	**36.01**	**57.09**	**30.51**
RDF Stoker-fired Excluding Boiler Costs							
Ames	IA	200	14.77	73.85	30.86	40.11	N/A
Madison	WI	400	4.49	11.24	21.60	23.66	13.37
S.W. Fuel Processing Facility		1,000	48.79	48.79	13.37	24.69	3.09
Baltimore County	MD	1,200	22.28	18.57	26.74	N/A	N/A
Average		**700**	**22.58**	**38.11**	**23.14**	**29.49**	**8.23**
RDF Co-fired with Pulverized Coal							
Lakeland	FL	200	7.70	38.48	12.42	34.28***	20.93
Madison	WI	400	18.16	45.39	28.50	N/A	N/A
Retrofit 2-50 MW boiler units*		310	9.89	31.89	15.5^^	-6.71****	N/A
New 2-200 MW boiler units*		1,150	26.69	23.21	7.9^^	-7.11****	N/A
New 2-500 MW boiler units*		2,780	42.01	15.11	4.8^^	-7.35****	N/A
Average		**968**	**20.89**	**30.82**	**13.82**		**20.93**

* Costs for the unit are the incremental costs for the use of RDF in coal-fired power plants.
Costs are converted to equivalent MSW basis. Co-firing design bases and assumptions are as follows:

- RDF contribution ≈ 15% of total heat input
- Heating value of RDF ≈ 5,900 Btu/lb
- Load factor = 0.65.

** After crediting the sales value of electricity, the net surplus to the project is $10.68/ton of MSW.

*** The net cost of fuel (total cost-credit) is $15.87/ton of RDF.

**** These incremental O & M credits represent the equivalent fuel savings to the power boilers. They also represent the breakeven cost of the RDF for cofiring in normally coal-fired boilers.

^ The capacity of the plant is being expanded from 2,000 to 3,000 TPD.

^^ These O&M are derived from estimated cost in kWh.

General note: The project status of individual plant is of 1990, reported by Government Advisory Associates (GAA) in 1991.

Sources: References 10 &11.

Table I.7

COMPARISON OF CAPITAL COSTS FOR COMBUSTION PROCESSES

COSTS IN CURRENT DOLLARS

Technology	Start-up Period	No. of Facility	Average Capital Cost ($/Ton/Day)
Modular	1975-1982	21	35,900
Modular	1983-1993	27	72,300
Modular	1975-1993	48	62,500
Mass burn	1964-1982	8	21,300
Mass burn	1983-1994	83	114,000
Mass burn	1964-1994	91	108,500
Refuse derived fuel (RDF)	1970-1982	5	75,100
Refuse derived fuel (RDF)	1983-1994	17	101,900
Refuse derived fuel (RDF)	1970-1994	22	95,500

Source: Waste Age, p.156, Nov., 1990.

Table I.8

CAPITAL AND OPERATING COSTS OF MSW COMPOSTING PROJECTS

ALL COSTS NORMALIZED TO 1991 COST INDEX

Project Name	State	Equivalent MSW Capacity (Tons/day)	Capital Investment ($ Million)	Unit Capital Cost ($1,000/ton/day)	O & M Cost Excluding Debt Service Charges ($/ton)	O & M Cost Including Debt Service Charges ($/ton)	Tipping Fee ($/ton)
Lake of the Woods, Graceton	MN	10	0.42	42.27	72.14	N/A	*
Portage Co-composting, Portage	WI	16	1.03	64.38	176.37	N/A	N/A
Filmore County Composting	MN	18	0.72	40.11	49.32	N/A	72.00
Berrien County RR Authority	GA	20	N/A	N/A	N/A	N/A	N/A
Bedmin. Bioconversion, Big Sandy	TX	25	0.77	30.86	N/A	N/A	N/A
Swift County Composting, Benson	MN	25	1.66	66.40	N/A	N/A	72.00
Pennington County, Thief River Falls	MN	40	1.34	33.50	29.87	N/A	46.29
Sumiter County, Sumterville	FL	50	5.14	40.26	N/A	N/A	51.43
Pena-Ayala Co., Edingburg	TX	80	N/A	N/A	N/A	N/A	N/A
Resource Recovery, Inc., Coffeeyville	KS	80	N/A	N/A	N/A	N/A	15.43
Recomp, Inc., St. Cloud	MN	100	7.71	7.86	N/A	N/A	78.17
Addington Environ., Inc. Ashland	KY	150	N/A	N/A	N/A	N/A	N/A
TRS Industries, Des Moins	IA	200	4.32	21.60	N/A	N/A	22.24
Agripost, Inc., Dade County	FL	350	30.86	88.16	2.35	N/A	26.74
Riedel Oregon Compost, Portland	OR	600	30.86	51.43	N/A	N/A	69.94
Delaware Reclamation, Wilmington	DE	1,000	73.54	73.54	N/A	N/A	46.29
Average		173	13.20	46.70	66.01	N/A	50.05

* Levied as a tax at $2.18/household/mo.

Sources: References 10 &11.

Table I.9

CAPITAL AND OPERATING COSTS OF MATERIAL RECOVERY/RECYCLING FACILITIES (MRF)

ALL COSTS NORMALIZED TO 1991 COST INDEX

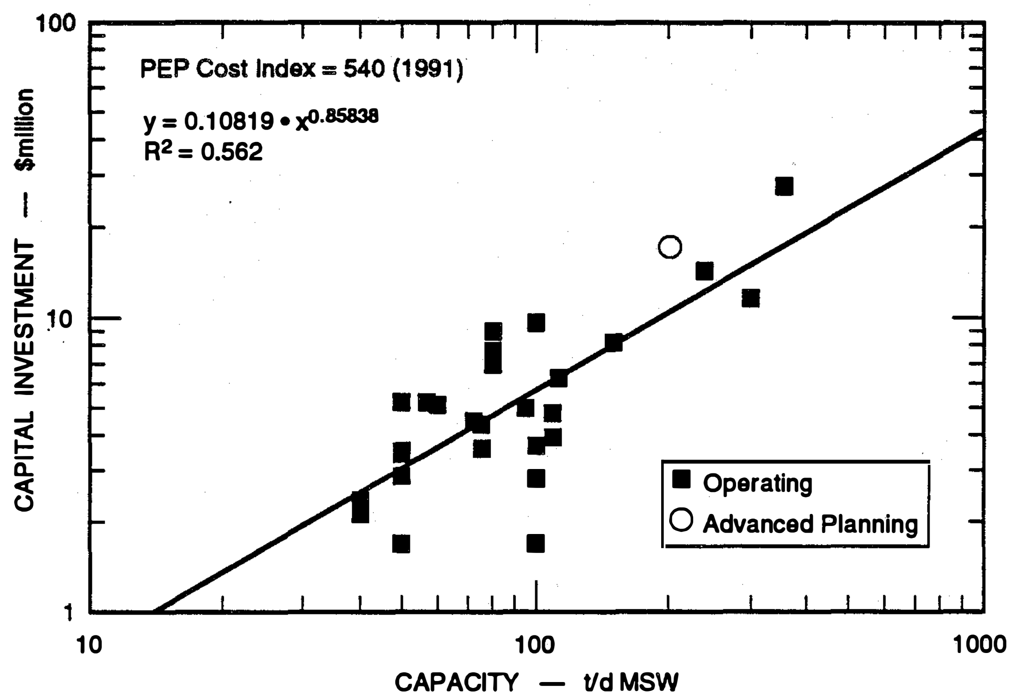
Project Name	State	Capacity (Tons/day)	Capital Investment ($1,000)	Unit Capital Cost ($1,000/ton/day)	O & M Cost Excluding Debt Service Charges ($/ton)	O & M Cost Including Debt Service Charges ($/ton)
Facilities in Operation - Low Tec						
Garden City Disposal	NJ	2	105.9	52.9	58.2	N/A
York Waste Disposal	PA	2	158.8	79.4	N/A	N/A
Susquehanna County	PA	5	44.5	8.9	N/A	N/A
Phoenix	AZ	10	11.6	1.2	51.9	N/A
Meyer Brothers Scavenger Service	IL	11	272.2	24.7	28.6	N/A
York County (Rewcycle America)	PA	30	1,588.2	52.9	N/A	N/A
Atlantic County	NJ	37	243.5	6.6	48.7	N/A
Ramsey County (Super Cycle MRF)	MN	43	572.1	13.3	N/A	63.5
East Bay Disposal (Durham Rd.)	CA	55	397.1	7.2	N/A	N/A
Seattle (Recycle America)	WA	110	544.4	4.9	N/A	31.8
Somerset county	NJ	125	6,251.1	50.0	137.6	N/A
Average		**39**	**926.3**	**27.5**	**65.00**	**47.65**
Facilities in Operation - High Tec						
Groton	CT	23	390.4	17.0	5.30	8.50
Monmouth County	CA	25	130.7	5.2	N/A	24.40
Philadelphia Transfer & Recycling	PA	35	423.5	12.1	N/A	N/A
Monmouth County Recycling Corp.	CA	43	1,169.9	27.2	22.20	N/A
Bristol	PA	45	3,810.9	84.7	N/A	70.90
New York City (East Harlem)	NY	55	3,919.8	71.3	64.60	N/A
Camden County	NJ	70	797.5	11.4	73.00	N/A
West Paterson (WPAR)	NJ	70	1,197.7	17.1	N/A	N/A
Westbury	CT	75	435.5	5.8	N/A	N/A
Seattle (Rabanco)	WA	85	6,532.9	76.9	N/A	N/A
Marin Recycling & R.R. Center	CA	100	11,528.1	115.3	N/A	N/A
Johnston MRF	RI	130	6,670.0	51.3	30.70	N/A
Distributors Recycling	NJ	250	4,001.9	16.0	N/A	N/A
Syracuse	NY	400	3,810.9	9.5	N/A	N/A
Average		**100**	**3,201.4**	**37.2**	**39.16**	**34.60**

Reference: Appendix E, wTe.

Figure I.4

MODULAR MASS BURN - STEAM PRODUCTION ONLY PLANTS

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]

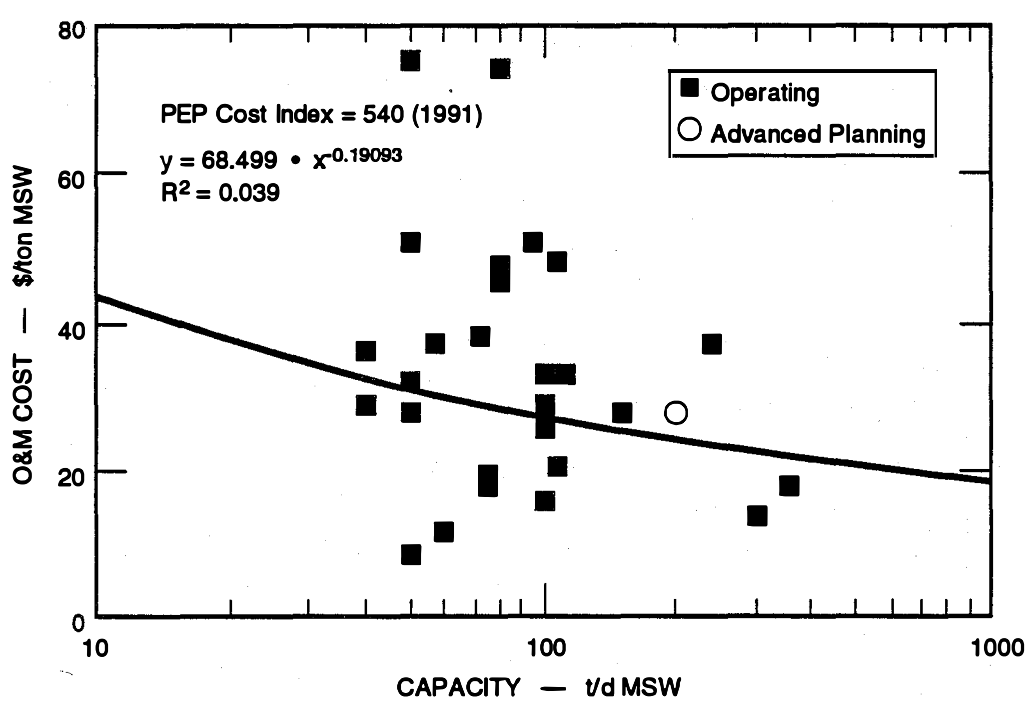


[a] Excluding costs associated with collection (e.g., trucks).

Figure I.5

MODULAR MASS BURN - STEAM PRODUCTION ONLY PLANTS

EFFECT OF PLANT CAPACITY ON O&M COSTS[b]

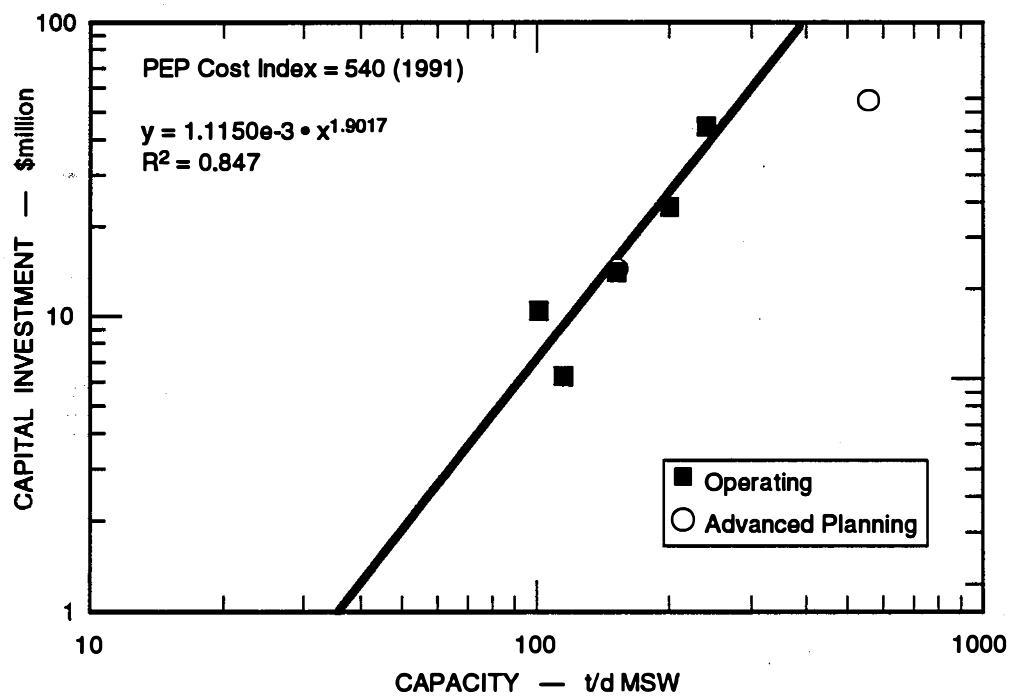


[b] Excluding operating cost associated with collection.

Figure I.6

MODULAR MASS BURN - ELECTRICITY PRODUCTION ONLY PLANTS

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]

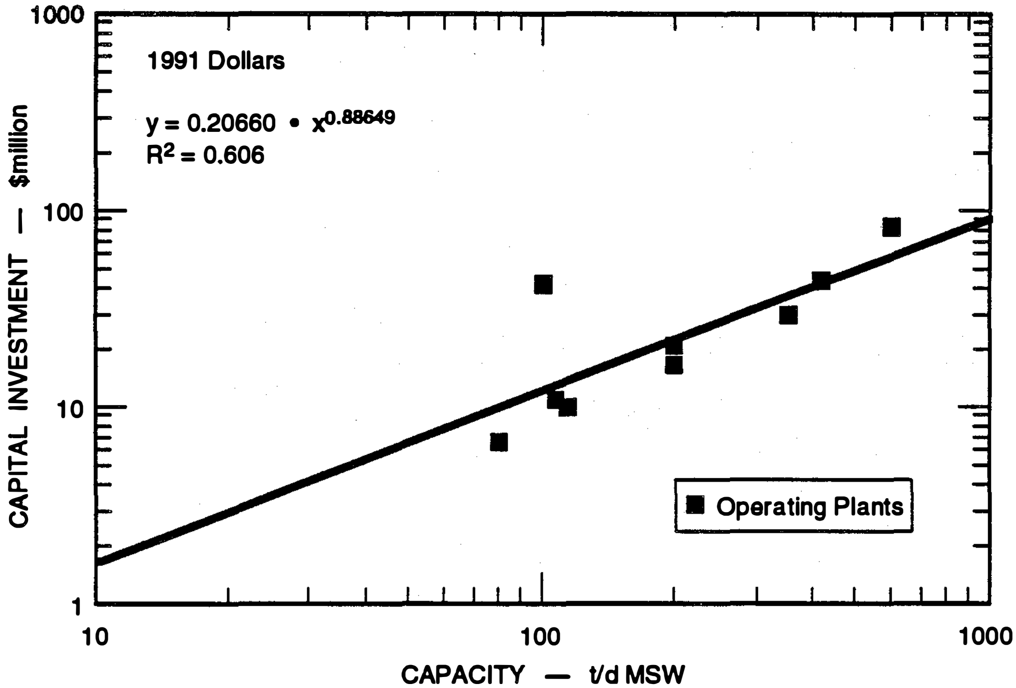


[a] Excluding costs associated with collection (e.g., trucks).

Figure I.7

MODULAR MASS BURN - STEAM/ELECTRICITY PRODUCTION PLANTS

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]

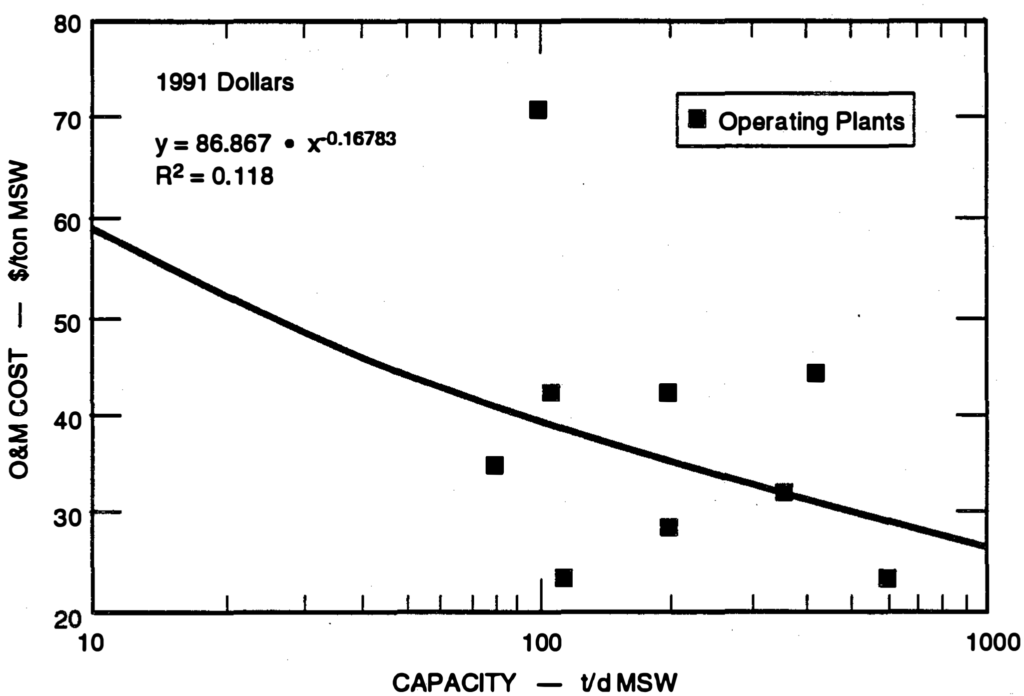


[a] Excluding costs associated with collection (e.g., trucks).

Figure I.8

MODULAR MASS BURN - STEAM/ELECTRICITY PRODUCTION PLANTS

EFFECT OF PLANT CAPACITY ON O&M COSTS[b]

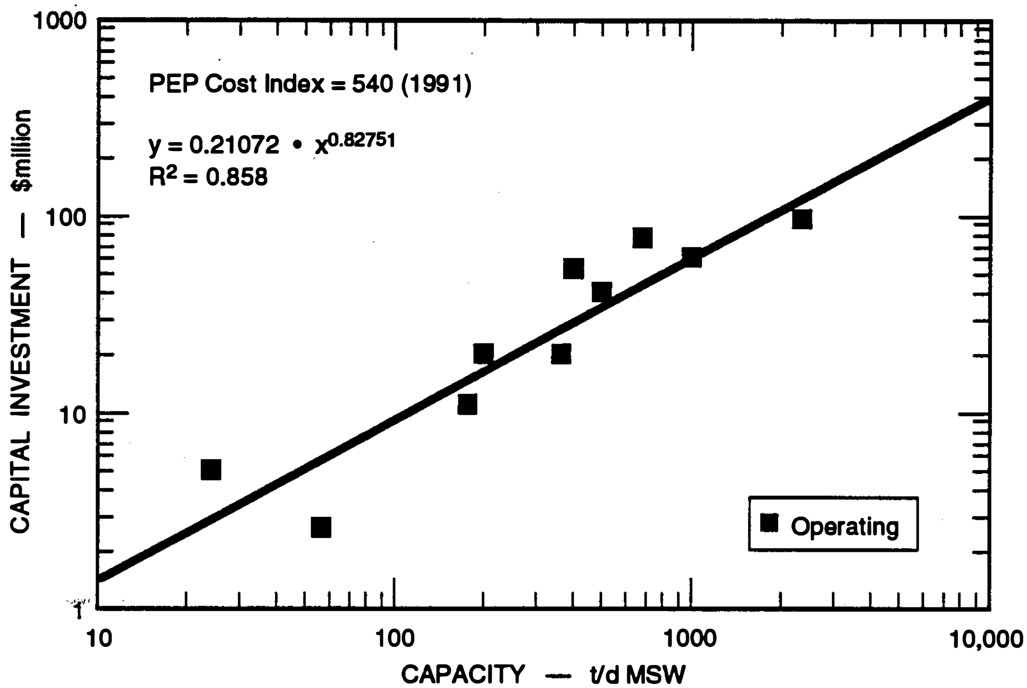


[b] Excluding operating costs associated with collection.

Figure I.9

FIELD-ERECTED MASS BURN - STEAM PRODUCTION PLANTS

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]

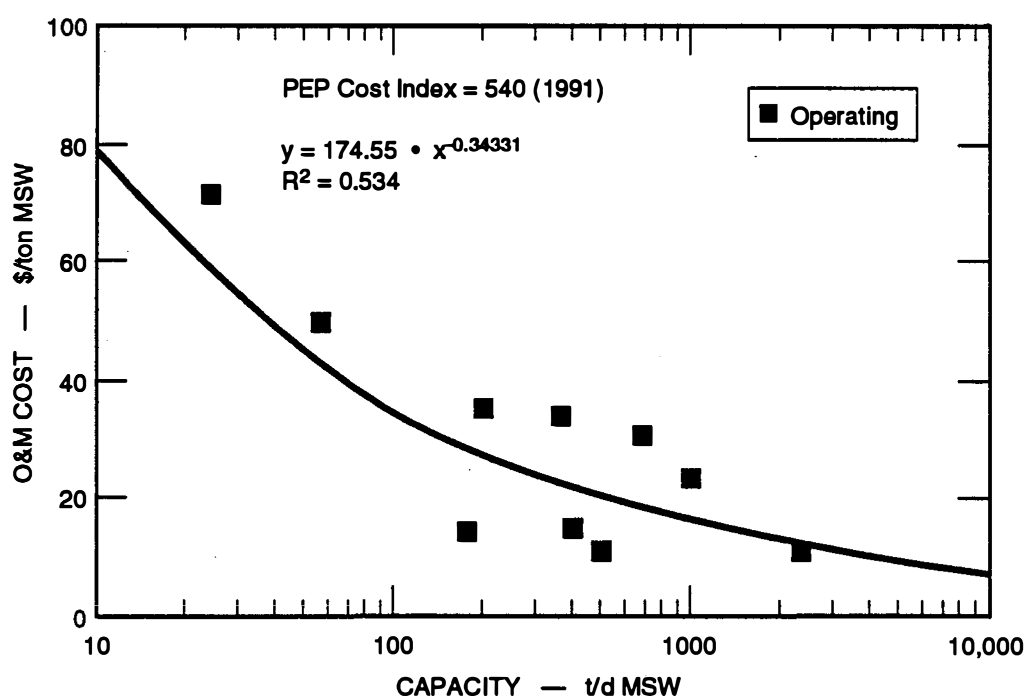


[a] Excluding costs associated with collection (e.g., trucks).

Figure I.10

FIELD-ERECTED MASS BURN - STEAM PRODUCTION PLANTS

EFFECT OF PLANT CAPACITY ON O&M COSTS[b]

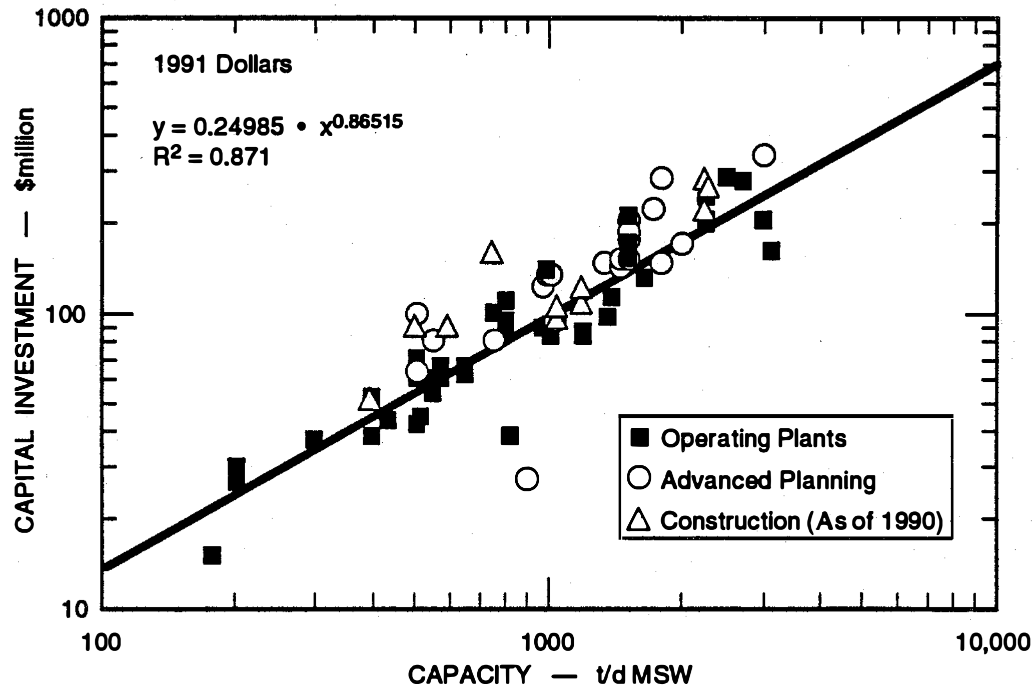


[b] Excluding operating cost associated with collection.

Figure I.11

FIELD ERECTED MASS BURN - ELECTRICITY PRODUCTION PLANTS

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]

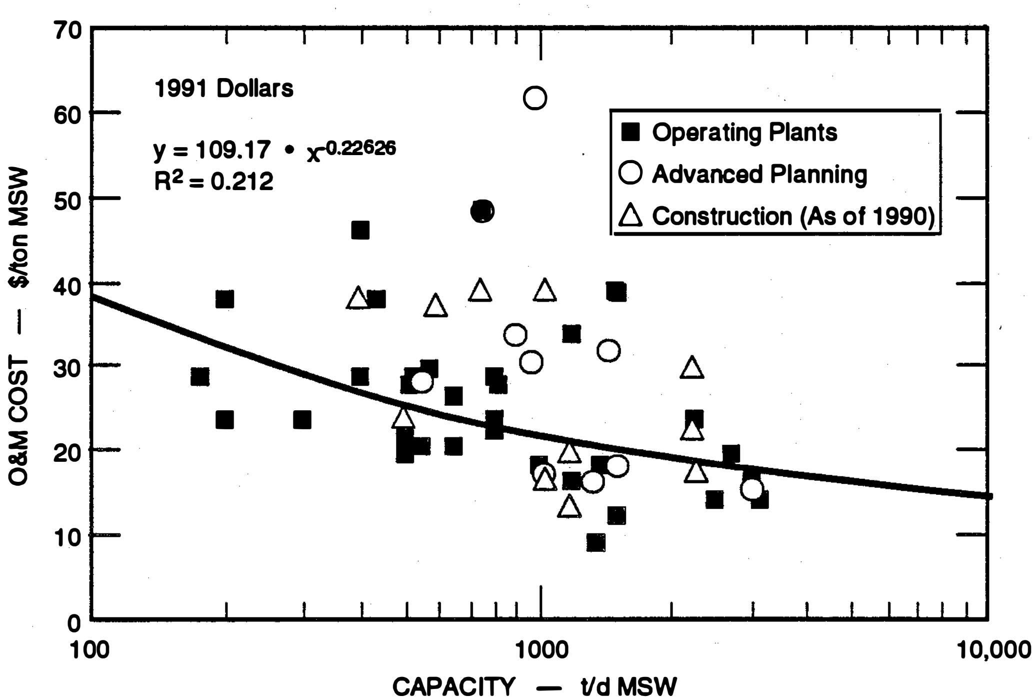


[a] Excluding costs associated with collection (e.g., trucks).

Figure I.12

FIELD ERECTED MASS BURN - ELECTRICITY PRODUCTION PLANTS

EFFECT OF PLANT CAPACITY ON O&M COSTS[b]

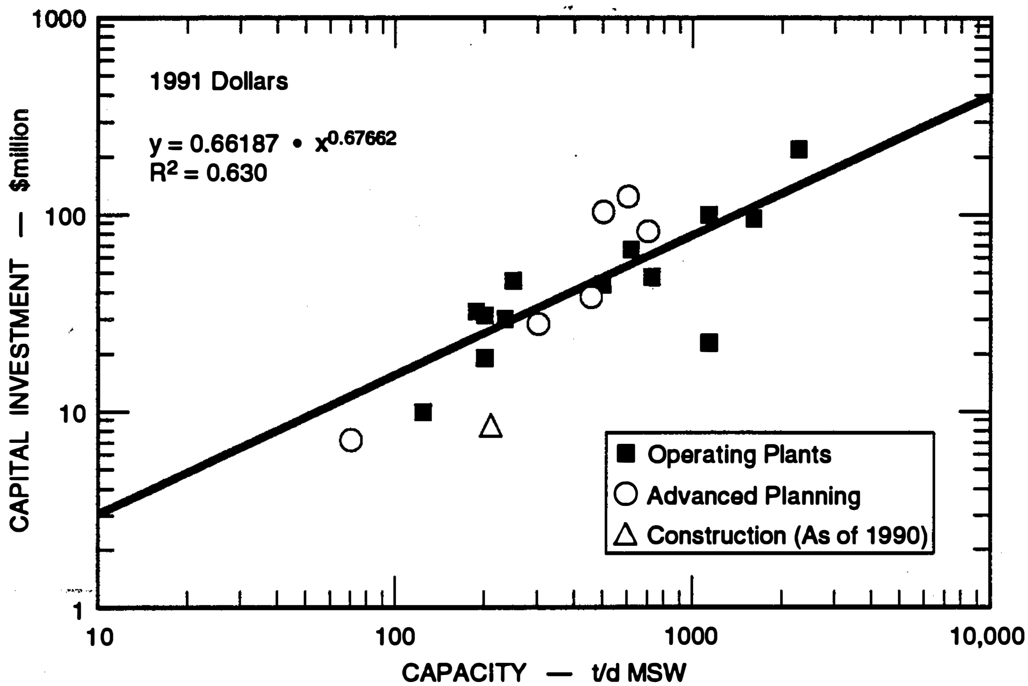


[b] Excluding operating costs associated with collection.

Figure I.13

FIELD-ERECTED MASS BURN - STEAM/ELECTRICITY PRODUCTION PLANTS

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]

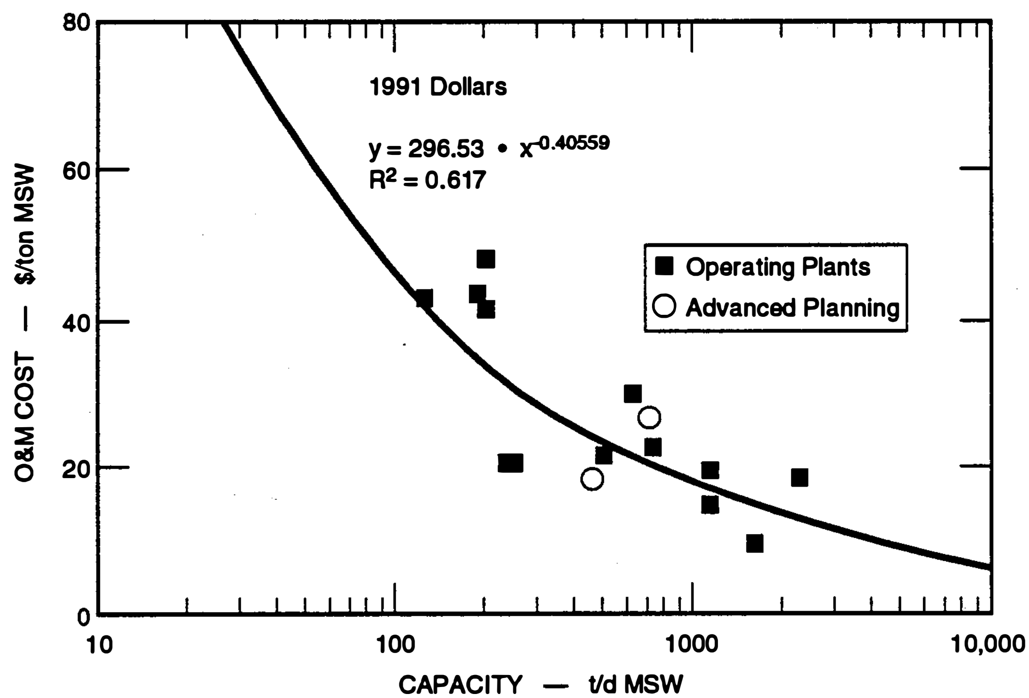


[a] Excluding costs associated with collection (e.g., trucks).

Figure I.14

FIELD-ERECTED MASS BURN - STEAM/ELECTRICITY PRODUCTION PLANTS

EFFECT OF PLANT CAPACITY ON O&M COSTS[b]



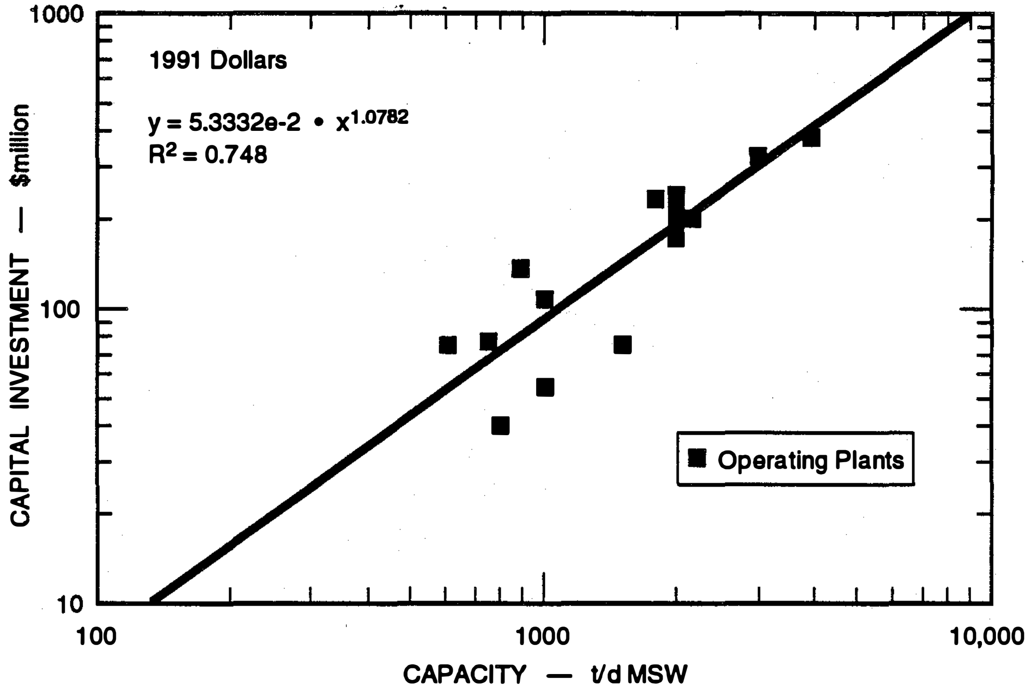
[b] Excluding operating costs associated with collection.

Figure I.15

RDF SPREADER STOKER-FIRED ELECTRICITY PRODUCTION PLANTS

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]

(Boiler Cost Included)



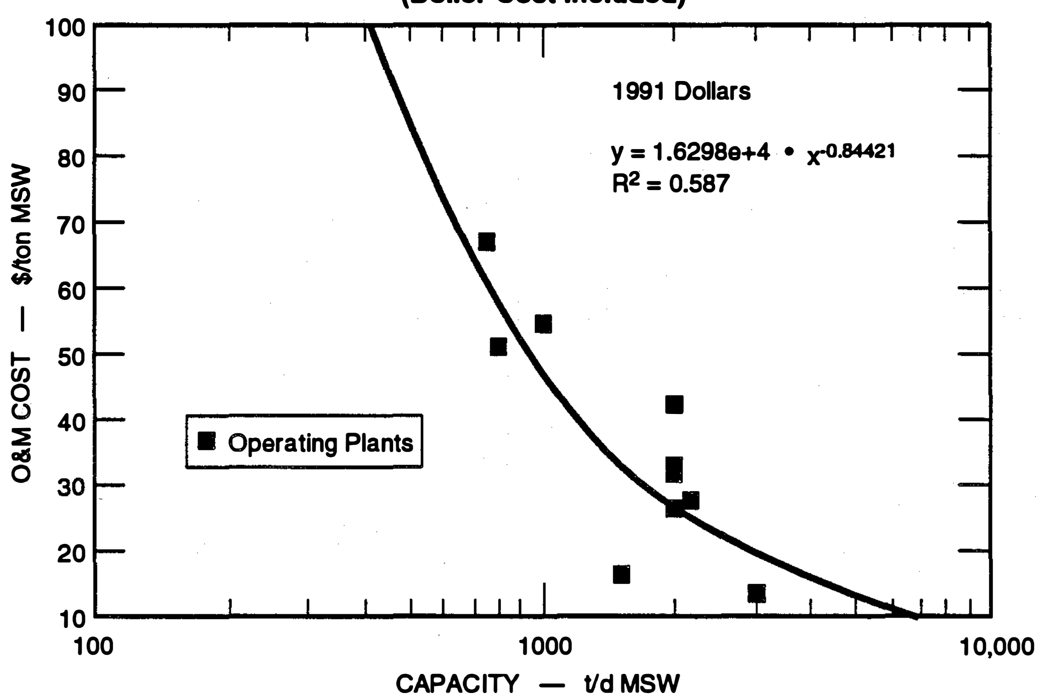
[a] Excluding costs associated with collection (e.g., trucks).

Figure I.16

RDF SPREADER STOKER-FIRED ELECTRICITY PRODUCTION PLANTS

EFFECT OF PLANT CAPACITY ON O&M COSTS[b]

(Boiler Cost Included)

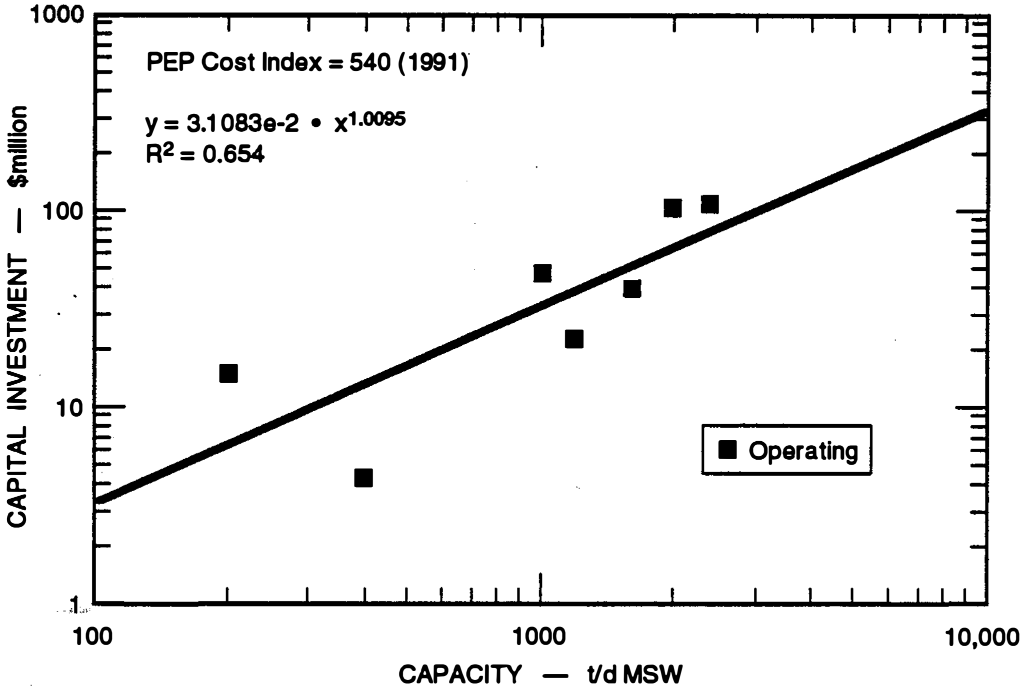


[b] Excluding operating cost associated with collection.

Figure I.17

RDF SPREADER STOKER-FIRED BOILER PLANTS

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]
(Boiler Cost Excluded)

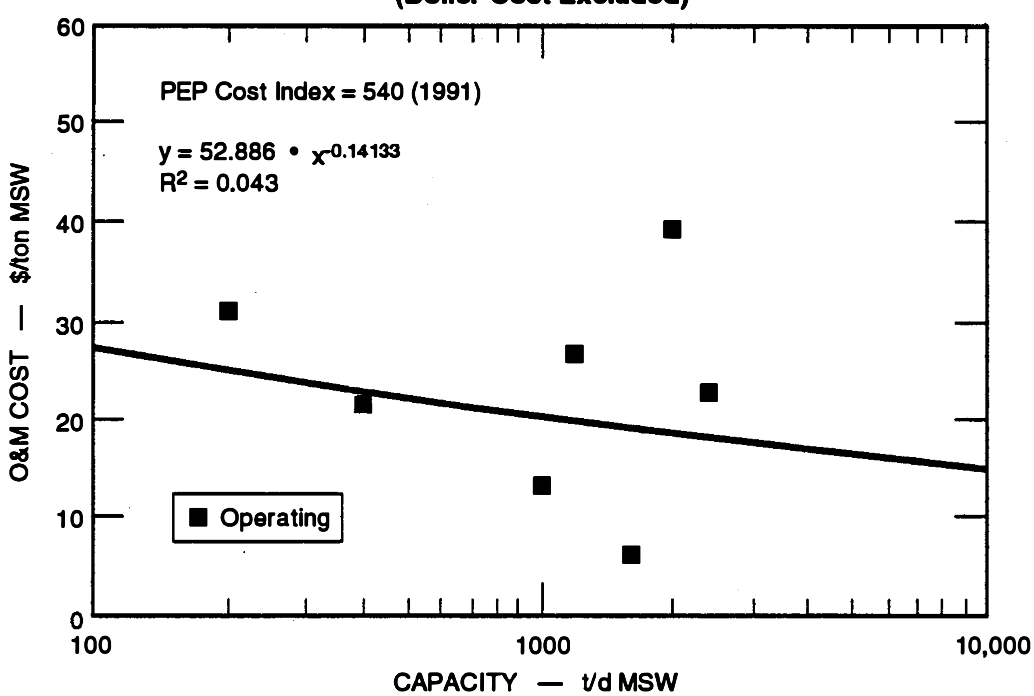


[a] Excluding costs associated with collection (e.g., trucks).

Figure I.18

RDF SPREADER STOKER-FIRED BOILER PLANTS

EFFECT OF PLANT CAPACITY ON O&M COSTS[b]
(Boiler Cost Excluded)

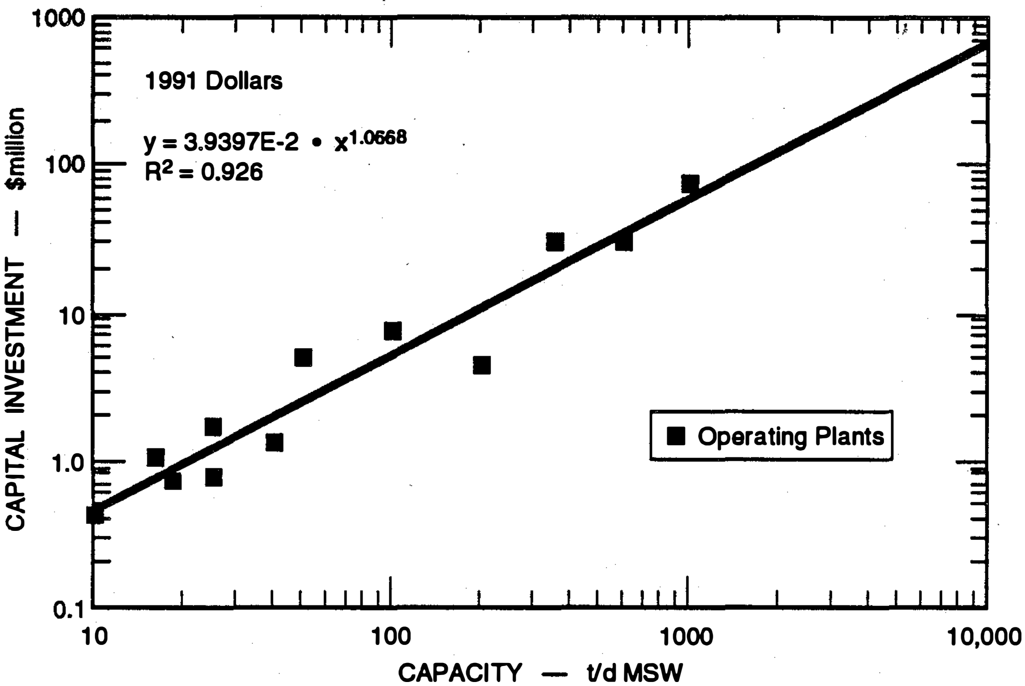


[b] Excluding operating cost associated with collection.

Figure I.19

COMPOSTING OF MSW

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]

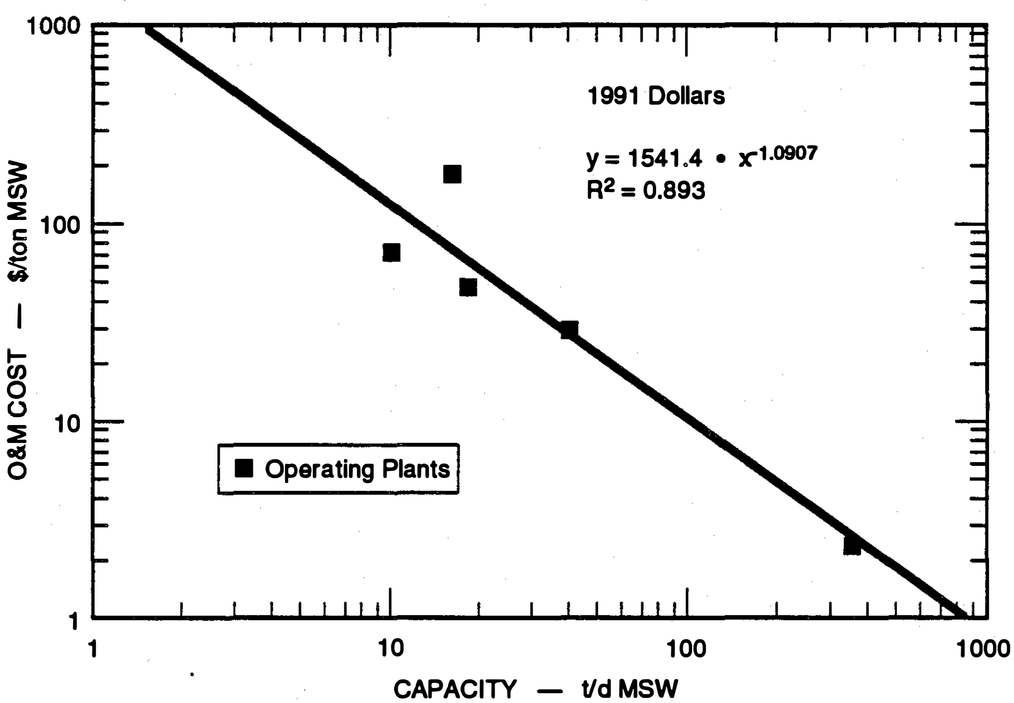


[a] Excluding costs associated with collection (e.g., trucks).

Figure I.20

COMPOSTING OF MSW

EFFECT OF PLANT CAPACITY ON O&M COSTS[b]

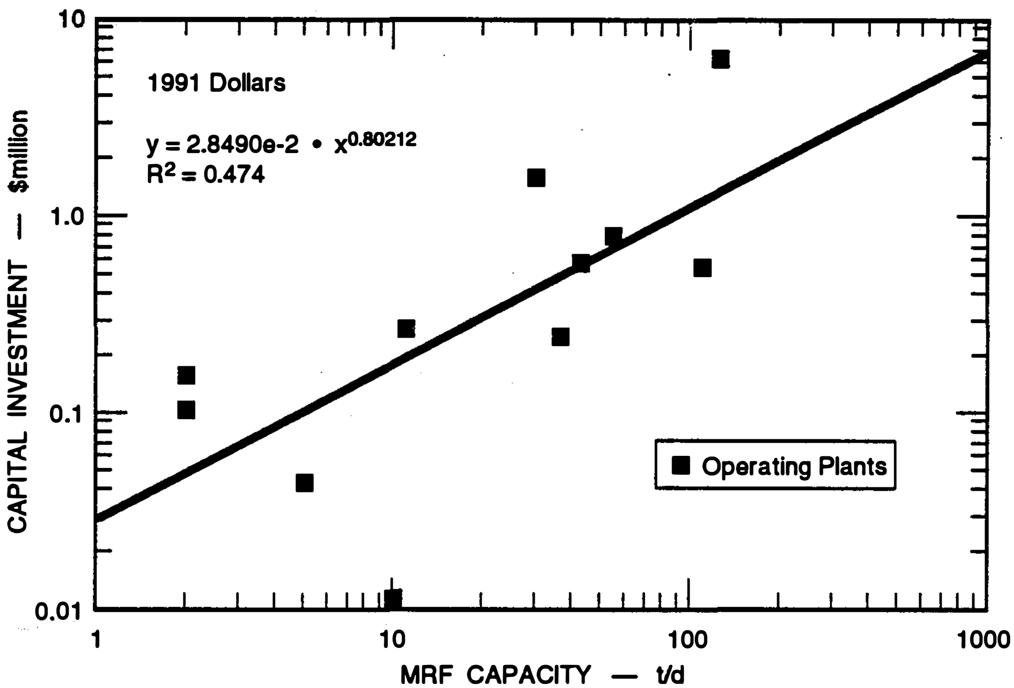


[b] Excluding operating cost associated with collection.

Figure I.21

MATERIALS RECYCLING FACILITIES (MRF)

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]
(Low Technology)

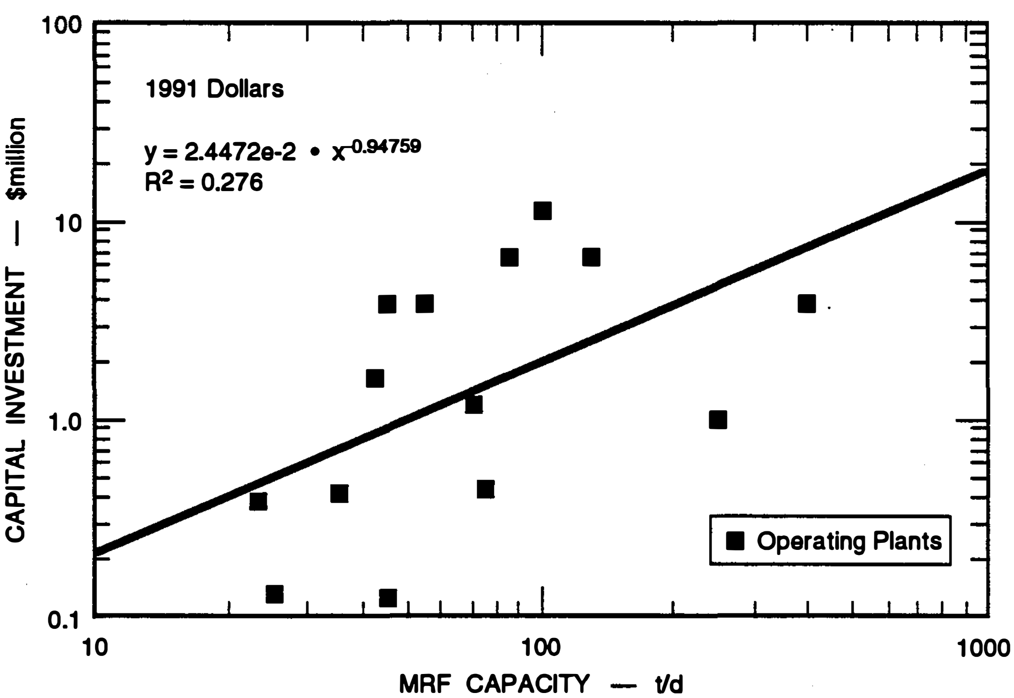


[a] Excluding costs associated with collection (e.g., trucks).

Figure I.22

MATERIALS RECYCLING FACILITIES (MRF)

EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT[a]
(High Technology)

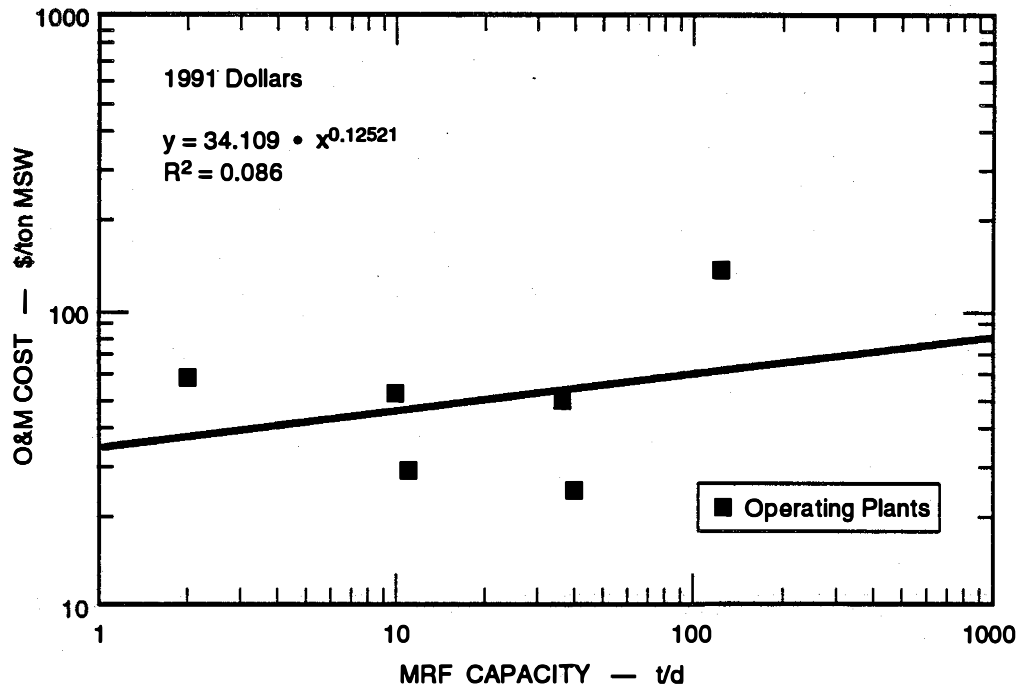


[a] Excluding costs associated with collection (e.g., trucks).

Figure I.23

MATERIALS RECYCLING FACILITIES (MRF)

EFFECT OF PLANT CAPACITY ON O&M COSTS[a]
(Low Technology)

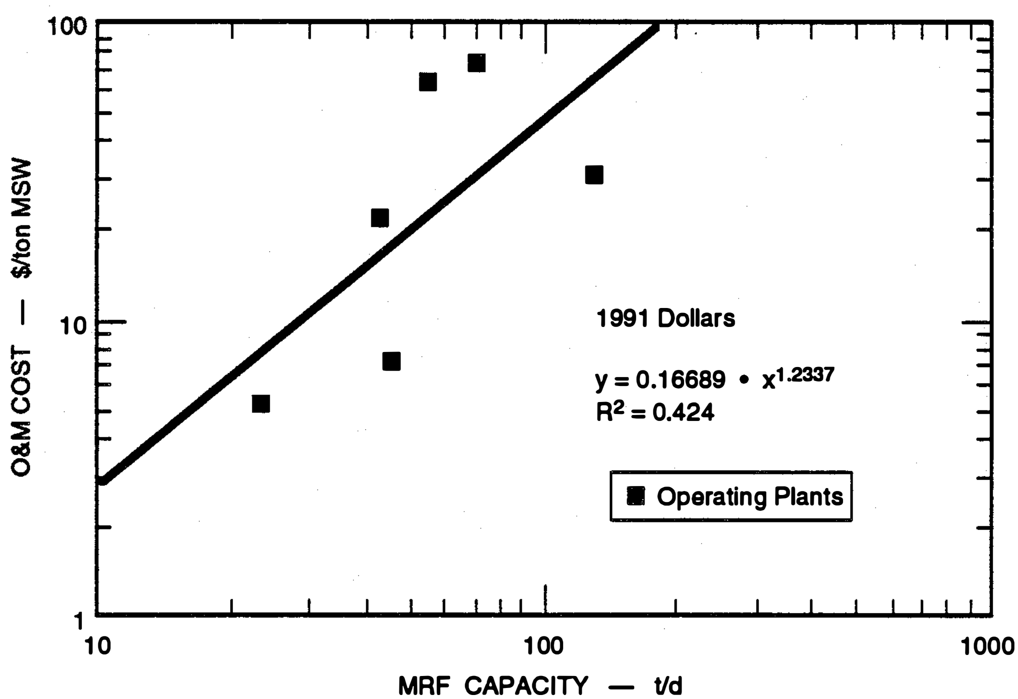


[a] Excluding debt service charges and operating costs associated with collection.

Figure I.24

MATERIALS RECYCLING FACILITIES (MRF)

EFFECT OF PLANT CAPACITY ON O&M COSTS[a]
(High Technology)



[a] Excluding debt service charges and operating costs associated with collection.

Exhibit II

DATA BASE FOR CALCULATING ENERGY BALANCES AND ENVIRONMENTAL RELEASES

STRUCTURE AND PURPOSES OF THE DATA BASE

The following pages include the calculated values and assumptions used for deriving the data for comparing the environmental releases and energy balances of the various technologies and combinations. The data base is divided into two parts: Basic Worksheets and Strategy Worksheets.

The Basic worksheets describe each unit operation on the basis of a ton of material fed to that operation. For example, the Basic worksheet on MRFs assumes that 2,000 pounds of recyclables are sent to the MRF. Similarly, for composting or RDF firing, the energy and emissions derived from 1 ton of feed to the unit operation are calculated.

In the Strategy worksheets, the various unit operations, as defined in the tables, are combined into an overall waste management technology, and the various fractions of MSW are apportioned by their ability to handle the waste. For example, curbside recycling, which might take 10% of all the MSW, is combined with RDF preparation, which recovers 80% of the MSW fed to it as RDF; the RDF, in turn would be sent for anaerobic digestion, which has another set of conversion efficiencies as defined in the Basic worksheet. The Strategy worksheet thus creates a mass and energy balance and calculates the inputs and outputs in correct proportion for the entire strategy

The database will be provided in Lotus 1-2-3 format. It will be accompanied by instructions explaining how to change the values to customize the data base for an individual community or to reflect different data or assumptions.

The data base is only intended for comparing these MSW management strategies. It cannot:

- Predict future growth rates of MSW
- Predict amount or composition of MSW
- Optimize or integrate collection routing for MSW pickup or curbside collection
- Account for energy impacts or raw material impacts when a recycled material is used for applications other than its original use.*
- Correlate MSW generation or composition with demographic variables, socioeconomic class, proportion of single-family homes or apartment houses, or any other factor.†

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* That omission is not intended to imply that alternative uses are disadvantageous.

† Tellus Institute has developed a model, called "WastePlan," that can provide such correlations.

Specific assumptions and sources of information are identified in the footnotes; however, two important general comments should be noted:

1. The data base uses Btu values for transportation applications as Btus of the fuel used. Btus that were used as electricity in the process are reported as Btus required to generate the required electricity in a good fossil-fuel-fired plant

2. The data base used the experience of one community—Palo Alto, California (population 57,000)—to obtain estimates of routing miles, truck loadings, and mileage. Palo Alto is an affluent community that has had an aggressive curbside recycling program since 1978. A year-round curbside compost collection program was initiated in 1990; the energy expenditure and emissions analysis of curbside yard waste collection based on data for Palo Alto is very unfavorable. The data provides a strong note of caution for the activity, but additional case studies would be important before ruling the method out.

DATA BASE USER GUIDE

This guide describes the details of how the data base is structured and provides specific examples of how to make changes in the data or assumptions in the data base. The instructions here cover only the data base developed for this analysis of MSW management technologies. Please refer to a DOS manual and a Lotus 1-2-3 manual for general information related to operating the computer or running the 1-2-3 application.

Getting Started

You will need the following hardware to run the electronic worksheets:

- IBM PC AT or compatible
- Hard disk with 5 MB available
- 1 MB of available system RAM
- EGA, VGA, high-resolution CGA, or Hercules Graphics Adapter for WYSIWYG display.

You will need the following software to run the electronic worksheets:

- Lotus 1-2-3 version 3.1 or higher
- DOS 3.0 or higher
- Microsoft Windows (for IBM or compatible; optional).

Spreadsheet Primer

Relationship Between Worksheets

The data base includes worksheets in two categories: 8 Basic worksheets and 15 strategy worksheets. The Basic worksheets provide data for individual technologies; the strategy worksheets attempt to illustrate the various pathways that could be taken by a ton of MSW being handled by selected combinations of the basic technologies.

Basic worksheets contain all the key assumptions about how a technology operates. Strategy worksheets *pull, proportion,* and *total* the data from the Basic worksheets.

It is important to recognize the differences between these two categories of worksheets. *Do not* compare data among different Basic worksheets because the feeds (e.g., 1 ton of raw MSW, 1 ton of recycled products) are not the same. In addition, *do not* compare data between Basic worksheets and Strategy worksheets, because again the bases of the data are different. *Do* compare the data among Strategy worksheets because these data have all been converted to the same basis: 1 ton of MSW as set out for collection.

Before you use the worksheets, you should review the following descriptions and examples, as well as each worksheet, to understand the different relationships among worksheets. To increase your understanding of the contents of the worksheets, you might ask yourself the following key questions as you review them:

- What is the basis of the data in this worksheet? Per ton of feed? Per ton of MSW?
- Am I comparing data that are on the same basis?
- Does this worksheet cover the operation of a single technology or a series of technologies?
- What is the source of the data? Does the worksheet provide operating data for a technology, or have the values been calculated?

Description of the Basic Worksheets

Each Basic worksheet is a separate file. Data for individual technologies are located in the Basic worksheets listed at the top of page II-4.

These worksheets include all the key assumptions for technology inputs and outputs. *Changes in the technology inputs and outputs should be made **only** in these worksheets.* Also, references to the sources of data and assumptions concerning technology operations are given *only* in the footnotes to the Basic worksheets. Other assumptions (e.g., how much feed by weight of the MSW goes through the technology) are found in the Strategy worksheets.

All the data in the Basic worksheets are provided in terms of 1 ton (2,000 pounds) of feed at the beginning of a process. In some cases, the feed is 1 ton of MSW (e.g., MSW delivered to a landfill); however, most of the Basic worksheets have a feed other than MSW. For example, the feed to a MRF, is 1 ton of recyclable products (e.g., newsprint, glass, plastics, ferrous metals), not 1 ton of MSW.

Basic Worksheet	Technology
Collect.wk3	MSW pick-up Curbside collection Yard waste collection
Compost.wk3	Yard waste composting RDF composting Anaerobic digestion
Cofiring.wk3	RDF cofiring with coal
Gasific.wk3	Gasification
Landfill.wk3	MSW landfill Ash monofill
Massburn.wk3	Mass burn
MRF.wk3	MRF Metal recovery RDF preparation Recycling
RDFcombu.wk3	RDF combustion

Methods for changing data in the Basic worksheets are described in the later subsection entitled "Changing Data Assumptions." If you wish to add or delete columns or rows in one of the Basic worksheets, please refer to the Lotus 1-2-3 manual for step-by-step instructions. These types of changes can significantly affect the "links" with the Strategy worksheets; therefore, they are not trivial changes and should be carefully implemented.

Description of the Strategy Worksheets

The Strategy worksheets are electronically linked to specific Basic worksheets. These Strategy worksheets *pull* data from the Basic worksheets into columns labeled with the technology name. The Strategy worksheets pull data from as few as two Basic worksheets to as many as five, depending on the complexity of the strategy. Values will not appear in a Strategy worksheet unless all the Basic worksheets linked to the Strategy worksheet are open.

A Strategy worksheet represents a possible pathway that 1 ton of MSW might take. Each pathway always includes one or more collection processes.

All the data in a Strategy worksheet are based on *1 ton of MSW set out for collection* in a community. The MSW may be collected in a packer truck or a curbside collection truck. As you read the worksheet left to right, you will follow the original ton of MSW through different processes, and then follow the resulting outputs (e.g., RDF, ash) to the next set of processes. A typical path will including one or more of the following: collection , separation (e.g., material recovery), use (e.g., recycling, combustion), and disposal (e.g., landfilling). The original ton of MSW may go straight to a landfill (e.g., Strategy 1) or be proportioned to different paths.

For most strategies, the "percentage" row represents the proportion by weight of the original ton of MSW that goes through that process. For example, in Strategy 2, 2,000 pounds of MSW (100% of the weight of the MSW) goes through Mass Burn; however, 520 pounds of ash (26% of the weight of the ton of MSW) generated by the Mass Burn process must be sent to an ash monofill for disposal.

For comparison of these percentages, refer to Strategy 7, which adds a MRF before Mass Burn. In this case, the MRF diverts 200 pounds of recyclable products (10% of the weight of the original ton of MSW) from the Mass Burn pathway. Therefore, only 1800 pounds of MSW (90% of the weight of the ton of MSW) remain for Mass Burn. Accordingly, the amount to the ash monofill decreases accordingly, and 468 pounds of ash—23% (or 26% of 90%) of the weight of the ton of MSW—must be sent to an ash monofill. This example demonstrates how subsequent processes are proportioned to represent the percentage that remains for each upstream process.

Changing Data Assumptions

Energy, Emissions, and Effluent Data

The inputs and output for each technology should *only* be changed in the *Basic* worksheets. Changes in these worksheets will automatically change the linked strategies; therefore, *no* changes should be made the Strategy worksheets.

The following types of inputs and outputs can be changed:

Inputs

- Raw materials (e.g., raw MSW, feed)
- Water
- Energy required

Outputs

- Energy produced
- Net energy
- Air emissions, quantity by chemical compound
- Leachate, quantity by chemical compound
- Solid waste, by destination
- Recyclable products.

For example, to change the types or quantities of recyclable products picked up at the curb, open the "MRF.wk3" worksheet and change the data in the Curbside MRF column. That will automatically change the net energy from recycling these products in the MRF.wk3 worksheet, as well as in the worksheets for all the strategies that include curbside collection.

Transportation

The transportation data are given in the Transportation Sub-calculations section of the Collection worksheet, called "Collect.wk3." Changes can be made in each individual type of collection program—household, commercial, curbside, and yard waste. The values for the collection program are presented in the "Given" column, and the environmental and energy impacts of each program are given in the "Standards" column. These values can be changed as desired. Each change in any of these values in one type of collection program will automatically change the values in the "calculations" and the "summary table." These values in turn will change any Strategy worksheet that includes the type of collection program in which you have made changes. Note that changes in individual types of collection programs have to be made in separate steps.

The following types of assumptions can be changed:

Given: Collection Program

- Number of trucks used for collection per day
- Miles per truck traveled per day
- Tons picked up per truck per trip
- Number of trips per truck per day
- Miles per gallon per truck

Standards

- Million Btu per gallon
- Hydrocarbon emissions (pounds per Btu)
- Carbon monoxide emissions (pounds per Btu)
- Nitrogen oxides emissions (pounds per Btu)
- Particulates emissions (pounds per Btu).

Type 1 Collection Percentage

- Percentage of a community's MSW coming from households
- Percentage of a community's MSW coming from commercial sources.

Note that Type 1 Refuse Collection is assumed to come from either households or commercial sources; thereforefore, the Type 1 percentages should total 100%. The data base currently uses 50% for each one. To change the mix, you need only change the percentage of Household Refuse Collection at the bottom of the Household Refuse Collect Subcalculator worksheet. The percentage assumed for Commercial Collection will then be automatically updated.

Percentages

The amount of MSW that is processed with a particular technology can be changed *only* within each Strategy worksheet. The percentages are located in a row near the top of each Strategy worksheet. A percentage change automatically proportions the inputs and outputs of the technology located in that column. In addition, a change in a percentage will also automatically change the percentage for any downstream technologies. For example, if the percentage through mass burn is changed, the percentage to the ash monofill automatically changes. However, a percentage change will not automatically change a percentage located in a *different* Strategy worksheet that uses the same technology. For example, if the percentage through mass burn in Strategy 2 is changed, the percentage through mass burn in Strategy 7 will *not* automatically change.

Strategy #1							
Technology Description: Landfill with Gas Recovery							
TON UNIT: ton of MSW collected							
	(units)	Collection	Separation	Use	Landfill	TOTAL	Notes
INPUTS		Type 1	NONE	NONE	100%		
Raw MSW	(lbs/ton)	2,000.00			2,000.00		
Land Space	(Acres)				2.00E-05	2.00E-05	
Water	(gals/ton)				15.00	15.00	
Energy Required	(Btu/ton)	7.91E+04			1.85E+03	8.09E+04	1
OUTPUTS							
Energy Produced	(Btu/ton)	0.00E+00			2.20E+06	2.20E+06	
Net Energy	(Btu/ton)	-7.91E+04			2.20E+06	2.12E+06	
Air Emissions	(lbs/ton)						2
Particulates		0.02				0.02	
Carbon Monoxide		0.79				0.79	
Hydrocarbons		0.08				0.08	
Nitrogen oxides		0.32				0.32	
Air Emissions - L/F	(lbs/ton)						
Methane					14.34	14.34	
CO2					225.00	225.00	
CO2-Combustion					212.00	212.00	
NMOC					0.75	0.75	
Heavy Metals					NA	NA	
Water Effluent							
Process Effluent	(gal/ton)					0.00	
Leachate	(gal/ton)				80.00	80.00	
COD	(lbs/ton)				0.16	0.16	
TOC	(lbs/ton)				0.00	0.00	
AOX	(lbs/ton)				1.08	1.08	
Chloride	(lbs/ton)				1.13	1.13	
Sodium	(lbs/ton)				0.73	0.73	
Potassium	(lbs/ton)				0.60	0.60	
Arsenic	(lbs/ton)				0.09	8.60E-02	
Cadmium					3.00E-03	3.00E-03	
Chromium					1.63E-01	1.63E-01	
Copper					4.30E-02	4.30E-02	
Nickel					1.08E-01	1.08E-01	
Lead					4.80E-02	4.80E-02	
Mercury					6.00E-03	6.00E-03	
Zinc					NA	NA	
Heavy Metals	(lbs/ton)				4.57E-01	0.46	
Solid Waste	(lbs/ton)				0.00	0.00	
Recyclable Products	(lbs/ton)				0.00	0.00	

Strategy #1
Technology Description: Landfill with Gas Recovery
Notes for Strategy 1:
Refer to SRI's Basic Worksheet-Collection for details on collection values.
Refer to SRI's Basic Landfill Worksheet for details on landfill values.

1) Due to availability of actual energy data (versus modeled data), Palo Alto refuse collection (50% household and 50% commercial) was used for Type 1. This data is appropriate for a community similar to Palo Alto; however, it should be customized to each community. Tellus Waste Plan Report, wTe Ref. 808, may be helpful for the task.

2) Air emissions for collection are described in the Basic Worksheet-Collection.

Strategy #2							
Technology Description: Mass Burn							
TON UNIT: ton of MSW collected							
	(units)	Collection	Separation	Mass Burn	Landfill	TOTAL	Notes
INPUTS		Type 1	MRF		Ash monofill		
Feed		2000	None	2000	545		
Percentage		100%		100%	27%		
Land Space	(Acres)				2.73E-06	2.73E-06	
Lime	(lbs/ton)			45		45.00	
Water	(gals/ton)			25	0	25.00	
Energy Required	(Btu/ton)	7.91E+04		1.51E+06	3.41E+02	1.59E+06	1
OUTPUTS							
Energy Produced	(Btu/ton)	0.00E+00		1.03E+07	0.00E+00	1.03E+07	
Net Energy	(Btu/ton)	-7.91E+04		8.78E+06	-3.41E+02	8.70E+06	
Air Emissions	(lbs/ton)						2
Particulates		0.02		7.00E-02		8.58E-02	
Carbon Monoxide		0.79		6.80E-01		1.47E+00	
Hydrocarbons		0.08		NA	0.00E+00	7.91E-02	
Nitrogen oxides		0.32		4.79E+00		5.11E+00	
Add't Air Emissions -MB	(lbs/ton)						
Total dioxin/furan				1.35E-08		1.35E-08	
SO2				2.45E+00		2.45E+00	
HCl				1.40E+00		1.40E+00	
HF				NA		0.00E+00	
CO2				1.65E+03		1.65E+03	
H2O				1.14E+03		1.14E+03	
Antimony				NA		0.00E+00	
Arsenic				4.10E-06		4.10E-06	
Cadmium				8.00E-06		8.00E-06	
Chromium				1.90E-05		1.90E-05	
Lead				1.00E-05		1.00E-05	
Mercury				2.30E-04		2.30E-04	
Beryllium				NA		0.00E+00	
Nickel				1.70E-05		1.70E-05	
Zinc				NA		0.00E+00	
Total Metals				2.88E-04	NA	2.88E-04	

Strategy #2							
Technology Description: Mass Burn							
TON UNIT: ton of MSW collected							
	(units)	Collection	Separation	Mass Burn	Landfill	TOTAL	Notes
Water Effluent							
Process Effluent	(gals/ton)			0.00		0.00	
L/F Leachate	(gal/Ton)				10.08	10.08	
COD	(lbs/ton)				0.00E+00	0.00E+00	
TOC	(lbs/ton)				2.73E-04	2.73E-04	
AOX	(lbs/ton)				NA	0.00E+00	
Chloride	(lbs/ton)				1.17E+00	1.17E+00	
Sodium	(lbs/ton)				2.62E-01	2.62E-01	
Potassium	(lbs/ton)				1.36E-01	1.36E-01	
Arsenic	(lbs/ton)				ND	0.00E+00	
Cadmium					ND	0.00E+00	
Chromium					ND	0.00E+00	
Copper					ND	0.00E+00	
Nickel					ND	0.00E+00	
Lead					ND	0.00E+00	
Mercury					ND	0.00E+00	
Zinc					ND	0.00E+00	
Heavy Metals	(lbs/ton)				ND	0.00E+00	
Solid Waste	(lbs/ton)						3
Solid Waste							
Ash				500		500.00	
Scrubber waste				45		45.00	
Recyclable Products	(lbs/ton)					0.00	

Strategy #2

Technology Description: Mass Burn

Notes for Strategy 2:

Refer to SRI's Basic Worksheet-Collection for details on collection values.
Refer to SRI's Basic Mass Burn Worksheet for details on mass burn values.
Refer to SRI's Basic Landfill Worksheet for details on monofill values.

1) Due to availability of actual energy data (versus modeled data), Palo Alto refuse collection (50% household and 50% commercial) was used for Type 1.
This data is appropriate for a community similar to Palo Alto; however, it should be customized to each community. Tellus Waste Plan Report, wTe Ref. 808, may be helpful for the task.

2) Air emissions for collection are described in the Basic Worksheet-Collection.

3) Ash is 25% of the weight of the MSW, or 5-15% by volume plus scrubber waste.
The ash from mass burn is non-hazardous under federal law by congressional mandate, however, ash may be hazardous under state laws.
Ash is often disposed in monofills

Strategy 3									
Technology Description: On-Site MRF and Mass Burn									
TON UNIT: ton of MSW collected									
	(units)	**Collection**	**Separation**	**Recycle**	**Mass Burn**	**Landfill**	**TOTAL**		**Notes**
INPUTS		**Type 1**	**Mixed MRF**	**(Credit-Recover)**		**Ash monofill**			
Percentage	(lbs/ton)	100%	100%	20%	80%	22%			1
Feed		2000	2000	400	1600				
ash						436			
Land	(acre)					2.18E-06			
Lime	(lbs/ton)				36		36		
Water	(gals/ton)				20	0	20		
Energy Required	(Btu/ton)	7.91E+04	1.10E+05		1.21E+06	2.73E+02	1.40E+06		2
OUTPUTS									
Energy Produced	(Btu/ton)			1.93E+06	8.23E+06	0.00E+00	1.02E+07		3
Net Energy	(Btu/ton)	-7.91E+04	-1.10E+05	1.93E+06	7.02E+06	-2.73E+02	8.76E+06		
Air Emissions	(lbs/ton)								4
Particulates		0.02			0.06		0.07		
Carbon Monoxide		0.79			0.54		1.33		
Hydrocarbons		0.08			NA	0.00	0.08		
Nitrogen Oxides		0.32			3.83		4.15		
Add'l Air Emissions-MB									
Total dioxin/furan					1.08E-08		1.08E-08		
SO2					1.96E+00		1.96E+00		
HCl					1.12E+00		1.12E+00		
HF					NA		0.00E+00		
CO2					1.32E+03		1.32E+03		
H2O					9.12E+02		9.12E+02		
Antimony					NA		0.00E+00		
Arsenic					3.28E-06		3.28E-06		
Cadmium					6.40E-06		6.40E-06		
Chromium					1.52E-05		1.52E-05		
Lead					8.00E-06		6.00E-06		
Mercury					1.84E-04		1.84E-04		
Beryllium					NA		0.00E+00		
Nickel					1.36E-05		1.36E-05		
Zinc					NA		0.00E+00		
Total Metals					2.30E-04		2.30E-04		

Strategy 3
Technology Description: On-Site MRF and Mass Burn
TON UNIT: ton of MSW collected

	(units)	Collection	Separation	Recycle	Mass Burn	Landfill	TOTAL		Notes
Water Effluent	(gals/ton)				2.30E-04		**2.30E-04**		
Process Effluent	(gals/ton)						**0.00**		
Leachate	(gals/ton)					8.07E+00	**8.07**		
COD	(lbs/ton)					0.00E+00	**0.00E+00**		
TOC	(lbs/ton)					2.18E-04	**2.18E-04**		
AOX	(lbs/ton)					NA	**0.00E+00**		
Chloride	(lbs/ton)					9.37E-01	**9.37E-01**		
Sodium	(lbs/ton)					2.09E-01	**2.09E-01**		
Potassium	(lbs/ton)					1.09E-01	**1.09E-01**		
Arsenic	(lbs/ton)					ND	**0.00E+00**		
Cadmium						ND	**0.00E+00**		
Chromium						ND	**0.00E+00**		
Copper						ND	**0.00E+00**		
Nickel						ND	**0.00E+00**		
Lead						ND	**0.00E+00**		
Mercury						ND	**0.00E+00**		
Zinc						ND	**0.00E+00**		
Heavy Metals	(lbs/ton)					ND	**0.00E+00**		
Solid Waste	(lbs/ton)								
ash					400.00		**400**		
Ash	(Percent of Input)				20%				
Scrubber Waste					36.00		**36**		
Recyclable Products	(lbs/ton)								
newspaper			183						
cardboard			37						
other paper			123						
aluminum			3						
glass			19						
plastic			16						
ferrous metals			19						
Total:			400				**400**		

Strategy 3
Technology Description: On-Site MRF and Mass Burn
Notes for Strategy 3:
Refer to SRI's Basic Worksheet-Collection for details on collection values.
Refer to SRI's Basic MRF Worksheet for details on MRF and Credit-Recovery values.
Refer to SRI's Basic Mass Burn Worksheet for details on mass burn values.
Refer to SRI's Basic Landfill Worksheet for details on monofill values.

1) Assume 20% of MSW is diverted for recycling after an on-site MRF operation. Refer to Basic MRF Worksheet.

2) Type 1 describes a MSW collection process.
Due to availability of actual energy data (versus modeled data), Palo Alto refuse collection (50% household and 50% commercial) was used for Type 1.
The data is good for a community similar to Palo Alto; however, it should be customized for each community. Tellus Waste Plan Report, wTe Ref. 808, may be helpful for the task.

Energy requirements for the different types of MRFs are described in the Basic MRF worksheet. .

3) The value for energy produced is not correct for Credit-Recover. However, it is correct for net energy.
In order for the spreadsheet to work, the net energy for Credit-Recover is also shown as energy produced.

4) Air emissions for collection are described in the Basic Worksheet-Collection.

Strategy #4									
Technology Description: RDF for Direct Firing									
TON UNIT: ton of MSW collected									
	(units)	Collection	Separation	Use	RDF	Landfill	Landfill		
		Type 1	RDF Prep.		Combustion				
INPUTS		MSW		(Credit-Metals)		MSW	Monofill	TOTAL	Notes
Percentage		100%	100%	4%	80%	16%	15%		
Raw MSW	(lbs/ton)	2000	2000	80	1600	320	297		
Land Space	(Acres)					3.20E-06	1.48E-06		
Limestone	(lbs/ton)				25				
Water	(gals/ton)				53	2.40	0.00E+00	55.20	
Energy Required	(Btu/ton)	7.91E+04	4.75E+05		1.60E+06	2.96E+02	1.86E+02	2.16E+06	
OUTPUTS									
Energy Produced	(Btu/ton)			3.12E+05	9.44E+06	3.52E+05	0.00E+00	1.01E+07	1
Net Energy	(Btu/ton)	-7.91E+04	-4.75E+05	3.12E+05	7.84E+06	3.52E+05	-1.86E+02	7.94E+06	2
	(kWh/ton)				364.00				
Air Emissions	(lbs/ton)								
Particulates		0.02			3.68E-02			0.05	
Carbon Monoxide		0.79			1.27E+00			2.06	
Hydrocarbons		0.08			NA			0.08	
Nitrogen oxides		0.32			2.33E+00			2.64	
Air Emissions - L/F	(lbs/ton)								
Methane						2.29	0.00	2.29	
CO2						36.00	0.00	36.00	
CO2-Combustion						33.92	0.00	33.92	
NMOC						0.12	0.00	0.12	
Heavy Metals						NA	NA	NA	
Add't Air Emissions -RDF	(lbs/ton)								
Total dioxin/furan					3.76E-09			3.76E-09	
SO2					1.10E+00			1.10E+00	
HCl					2.64E-01			2.64E-01	
HF					NA			NA	
CO2					1.39E+03			1.39E+03	
H2O					9.40E+02			9.40E+02	
Arsenic					ND			0.00E+00	
Cadmium					ND			0.00E+00	
Chromium					8.72E-05			8.72E-05	
Lead					3.20E-04			3.20E-04	
Mercury					5.52E-05			5.52E-05	
Nickel					6.40E-05			6.40E-05	
Zinc					1.70E-04			1.70E-04	
Total Metals					6.96E-04			6.96E-04	

Strategy #4									
Technology Description: RDF for Direct Firing									
TON UNIT: ton of MSW collected									
	(units)	Collection	Separation	Use	RDF	Landfill	Landfill		
		Type 1	RDF Prep.		Combustion				
Water Effluent									
Process Effluent	(gal/ton)							**0.00**	
Leachate	(gal/ton)					12.80	5.49	**18.29**	
COD	(lbs/ton)					2.56E-02	0.00E+00	**2.56E-02**	
TOC	(lbs/ton)					0.00E+00	1.48E-04	**1.48E-04**	
AOX	(lbs/ton)					1.73E-01	NA	**1.73E-01**	
Chloride	(lbs/ton)					1.81E-01	6.38E-01	**8.19E-01**	
Sodium	(lbs/ton)					1.17E-01	1.42E-01	**2.59E-01**	
Potassium	(lbs/ton)					9.60E-02	7.42E-02	**1.70E-01**	
Arsenic	(lbs/ton)					1.38E-02	ND	**1.38E-02**	
Cadmium						4.80E-04	ND	**4.80E-04**	
Chromium						2.61E-02	ND	**2.61E-02**	
Copper						6.88E-03	ND	**6.88E-03**	
Nickel						1.73E-02	ND	**1.73E-02**	
Lead						7.68E-03	ND	**7.68E-03**	
Mercury						9.60E-04	ND	**9.60E-04**	
Zinc						NA	ND	**0.00E+00**	
Total Heavy Metals	(lbs/ton)					7.31E-02	ND	**7.31E-02**	
Solid Waste	(lbs/ton)		0						
Ash	(lbs/ton)				272.00			**272.00**	3
Scrubber Sludge					24.80			**24.80**	
Recyclable Products	(lbs/ton)								
newspaper			0						
cardboard			0						
other paper			0						
aluminum			0						
glass			0						
plastic			0						
ferrous metals			80					**80.00**	
			80						

Strategy #4
Technology Description: RDF for Direct Firing
Notes for Strategy 4:
Refer to SRI's Basic Worksheet-Collection for details on collection values.
Refer to SRI's Basic MRF Worksheet for details on Metal Recovery and RDF Preparation and Credit-Recycling values.
Refer to SRI's Basic RDF Combustion Worksheet for details on combustion values.
Refer to SRI's Basic Landfill Worksheet for details on landfill and monofill values.

1) The value for energy produced is not correct for Credit-Metals. However, it is correct for net energy.
In order for the spreadsheet to work, the net energy for Credit-Metals is also shown as energy produced.
2) Credit-Metals is the net energy recovered from recycling the ferrous metals.
3) Ash is 17% of RDF plus scrubber waste. Reference wTe Appendix B pg B-52.

Strategy 5						
Technology Description: Yard Waste Composting + Landfill						
TON UNIT: ton of MSW collected						
		Collection	**Collection**	**Use**	**Landfill**	
		MSW	**Yardwaste**	**Composting**	**MSW**	
Percentage		**96%**	**4%**	**4%**	**96%**	
Feed	2000	**1920**	**80**	**80**	**1928**	
land					1.93E-05	**1.93E-05**
Water	(gals/ton)			8.88	14.46	**23.34**
Energy Required	(Btu/ton)	7.91E+04	2.25E+06	2.72E+03	1.78E+03	**2.33E+06**
OUTPUTS						
Energy Produced	(Btu/ton)	0.00E+00		0.00E+00	2.12E+06	**2.12E+06**
Net Energy	(Btu/ton)	-7.91E+04	-2.25E+06	-2.72E+03	2.12E+06	**-2.11E+05**
Air Emissions	(lbs/ton)					
Particulates		0.02	0.45			**0.46**
Carbon Monoxide		0.76	22.48			**23.24**
Hydrocarbons		0.08	2.25			**2.32**
Nitrogen oxides		0.30	8.99			**9.30**
L/F+Compost Gas Emissions	(lbs/ton)					
Methane	(lbs/Ton)				13.82	**13.82**
CO2	(lbs/ton)				216.90	**216.90**
CO2 Combustion					204.37	**204.37**
NMOC					0.72	**0.72**
Organics				NA		**0.00**
Heavy Metals					NA	**0.00**
Water Effluent	(gals/ton)					
Process Effluent	(gal/ton)					**0.00**
Leachate	(gal/ton)			0	77.12	**77.12**
COD	(lbs/ton)				1.54E-01	**1.54E-01**
TOC	(lbs/ton)				0.00E+00	**0.00E+00**
AOX	(lbs/ton)				1.04E+00	**1.04E+00**
Chloride	(lbs/ton)				1.09E+00	**1.09E+00**
Sodium	(lbs/ton)				7.04E-01	**7.04E-01**
Potassium	(lbs/ton)				5.78E-01	**5.78E-01**
Arsenic	(lbs/ton)				8.29E-02	**8.29E-02**
Cadmium					2.89E-03	**2.89E-03**
Chromium					1.57E-01	**1.57E-01**
Copper					4.15E-02	**4.15E-02**
Nickel					1.04E-01	**1.04E-01**
Lead					4.63E-02	**4.63E-02**
Mercury					5.78E-03	**5.78E-03**
Zinc					NA	**0.00E+00**
Total Heavy Metals					4.41E-01	**4.41E-01**
Solid Waste	(lbs/ton)			0		

Strategy 5							
Technology Description: Yard Waste Composting + Landfill							
TON UNIT: ton of MSW collected							
		Collection	Collection	Use	Landfill		
Recyclable Products	(lbs/ton)						
newspaper							
cardboard							
other paper							
aluminum							
glass							
plastic							
ferrous metals							
Total:						0.00	
Compost				56		56.00	

Strategy 5

Technology Description: Yard Waste Composting + Landfill

Notes for Strategy 5:

Refer to SRI's Basic Worksheet-Collection for details on the two types of collection values.
Refer to SRI's Basic Composting Worksheet for details on composting values.
Refer to SRI's Basic Landfill Worksheet for details on landfill values.

Strategy #6								
Technology Description: Curbside MRF + Landfill								
TON UNIT: ton of MSW collected								
	(units)	Collection	Collection	Separation	Recycling	Landfill		
		Type 1	Type 2	Curbside MRF				
INPUTS		MSW	Recyclables		(Credit)	MSW	TOTAL	Notes
Percentage		90%	10%	10%		91%		
Feed	(lbs/ton)	1800	200	200		1820		
Land Space	(Acres)					1.82E-05		
Water	(gals/ton)					14	13.65	
Energy Required	(Btu/ton)	7.12E+04	2.31E+04	2.00E+04		1.68E+03	1.16E+05	
OUTPUTS								
Energy Produced	(Btu/ton)				7.99E+05	2.00E+06	2.80E+06	1
Net Energy	(Btu/ton)	-7.12E+04	-2.31E+04	-2.00E+04	7.99E+05	2.00E+06	2.68E+06	
	(kWh/ton)							
Air Emissions	(lbs/ton)							
Particulates		0.01	4.61E-03				0.02	
Carbon Monoxide		0.71	0.23				0.94	
Hydrocarbons		0.07	0.02				0.09	
Nitrogen oxides		0.28	0.09				0.38	
Air Emissions - L/F	(lbs/ton)							
Methane						13.05	13.05	
CO_2						204.75	204.75	
CO_2-Combustion						192.92	192.92	
NMOC						0.68	0.68	
Heavy Metals						NA	0.00	
Water Effluent								
Process Effluent	(gal/ton)						0.00	
Leachate	(gal/ton)					72.80	72.80	
COD	(lbs/ton)					1.46E-01	1.46E-01	
TOC	(lbs/ton)					0.00E+00	0.00E+00	
AOX	(lbs/ton)					9.83E-01	9.83E-01	
Chloride	(lbs/ton)					1.03E+00	1.03E+00	
Sodium	(lbs/ton)					6.64E-01	6.64E-01	
Potassium	(lbs/ton)					5.46E-01	5.46E-01	
Arsenic	(lbs/ton)					7.83E-02	7.83E-02	
Cadmium						2.73E-03	2.73E-03	
Chromium						1.48E-01	1.48E-01	
Copper						3.91E-02	3.91E-02	
Nickel						9.83E-02	9.83E-02	
Lead						4.37E-02	4.37E-02	
Mercury						5.46E-03	5.46E-03	
Zinc						NA	0.00E+00	
Total Heavy Metals	(lbs/ton)					0.42	4.16E-01	
Solid Waste	(lbs/ton)					0.00		

Strategy #8								
Technology Description: Curbside MRF + Landfill								
TON UNIT: ton of MSW collected								
	(units)	**Collection**	**Collection**	**Separation**	**Recycling**	**Landfill**		
Recyclable Products	(lbs/ton)							
newspaper				108				
cardboard				8				
other paper				0				
aluminum				5				
glass				54				
plastic				1				
ferrous metals				5				
Total:				180			180.00	

Strategy #6
Technology Description: Curbside MRF + Landfill
Notes for Strategy 6:

Refer to SRI's Basic Worksheet-Collection for details on collection values.
Refer to SRI's Basic MRF Worksheet for details on MRF and Credit-Recycling values.
Refer to SRI's Basic Landfill Worksheet for details on landfill values.

1) The value for energy produced is not correct for Credit-Recycling. However, the net energy is correct.
In order for the spreadsheet to work, the net energy for Credit-Recycling is also shown as energy produced.

Strategy 7									
Technology Description: Curbside MRF + Mass Burn									
TON UNIT: ton of MSW collected									
	(units)	Collection	Collection	Separation	Recycling	Mass Burn	Landfill		
		Type 1	Type 2	Curbside MRF					
INPUTS		MSW	Recyclables		(Credit)		Monofill	TOTAL	Notes
Percentage		90%	10%	10%	10%	90%	25%		
Feed	(lbs/ton)	1800	200	200	200	1800	491		
Land Space	(Acres)			0			2.45E-06		
Lime	(lbs/ton)					41			
Water	(gals/ton)					23	0	22.50	
Energy Required	(Btu/ton)	7.12E+04	2.31E+04	2.00E+04		1.36E+06	3.07E+02	1.48E+06	
OUTPUTS									
Energy Produced	(Btu/ton)				7.99E+05	9.26E+06	0.00E+00	1.01E+07	1
Net Energy	(Btu/ton)	-7.12E+04	-2.31E+04	-2.00E+04	7.99E+05	7.90E+06	-3.07E+02	8.58E+06	
	(kWh/ton)					472.50			
Air Emissions	(lbs/ton)								
Particulates		0.01	4.61E-03			6.30E-02		0.08	
Carbon Monoxide		0.71	0.23			6.12E-01		1.55	
Hydrocarbons		0.07	0.02			NA		0.09	
Nitrogen oxides		0.28	0.09			4.31E+00		4.69	
Air Emissions - L/F	(lbs/ton)								
Methane							0.00	0.00	
CO2							0.00	0.00	
CO2-Combustion							0.00	0.00	
NMOC							0.00	0.00	
Heavy Metals							NA	0.00	
Add't Air Emissions -MB	(lbs/ton)								2
Total dioxin/furan						1.22E-08		1.22E-08	
SO2						2.21E+00		2.21E+00	
HCl						1.26E+00		1.26E+00	
HF						NA		NA	
CO2						1.49E+03		1.49E+03	
H2O						1.03E+03		1.03E+03	
Antimony						NA		0.00E+00	
Arsenic						3.69E-06		3.69E-06	
Cadmium						7.20E-06		7.20E-06	
Chromium						1.71E-05		1.71E-05	
Lead						9.00E-06		9.00E-06	
Mercury						2.07E-04		2.07E-04	
Beryllium						NA		0.00E+00	
Nickel						1.53E-05		1.53E-05	
Zinc						NA		0.00E+00	
Total Metals						2.59E-04		2.59E-04	

Strategy 7								
Technology Description: Curbside MRF + Mass Burn								
TON UNIT: ton of MSW collected								
	(units)	Collection Type 1	Collection Type 2	Separation Curbside MRF	Recycling	Mass Burn	Landfill	
Water Effluent								
Process Effluent	(gal/ton)							0.00
Leachate	(gal/ton)						9.07	9.07
COD	(lbs/ton)						0.00E+00	0.00E+00
TOC	(lbs/ton)						2.45E-04	2.45E-04
AOX	(lbs/ton)						NA	0.00E+00
Chloride	(lbs/ton)						1.05E+00	1.05E+00
Sodium	(lbs/ton)						2.35E-01	2.35E-01
Potassium	(lbs/ton)						1.23E-01	1.23E-01
Arsenic	(lbs/ton)						ND	0.00E+00
Cadmium							ND	0.00E+00
Chromium							ND	0.00E+00
Copper							ND	0.00E+00
Nickel							ND	0.00E+00
Lead							ND	0.00E+00
Mercury							ND	0.00E+00
Zinc							ND	0.00E+00
Heavy Metals	(lbs/ton)						ND	0.00E+00
Solid Waste	(lbs/ton)			0				
Ash	(lbs/ton)					450.00		450.00
Ash	(Percent of MSW feed)					23%		23%
Scrubber waste						40.50		40.50
Recyclable Products	(lbs/ton)						0.00	
newspaper				108				
cardboard				8				
other paper				0				
aluminum				5				
glass				54				
plastic				1				
ferrous metals				5				
Total:				180				180

Strategy 7

Technology Description: Curbside MRF + Mass Burn

Notes for Strategy 7:

Refer to SRI's Basic Worksheet-Collection for details on the two sets of collection values.
Refer to SRI's Basic MRF Worksheet for details on MRF and Credit-Recycling values.
Refer to SRI's Basic Mass Burn Worksheet for details on mass burn values.
Refer to SRI's Basic Landfill Worksheet for details on monofill values.

1) The value for energy produced is not correct for Credit-Recycling. However, it is correct for net energy.
In order for the spreadsheet to work, the net energy for Credit-Recycling is also shown as energy produced

Strategy 8

Technology Description: Curbside MRF + RDF for Direct Firing

TON UNIT: ton of MSW collected

	(units)	Collection	Collection	Separation	Separation	Use	Use	RDF	Landfill	Landfill		
		Type 1	Type 2	Curbside MRF	Metal Recovery							
INPUTS		MSW	Recyclables			C-Recycling	C-Metals	Combustion	MSW	Monofill	TOTAL	Notes
Percentage		90%	10%	10%	90%	10%	4%	72%	14%	13%		
Feed	(lbs/ton)	1800	200	200	1800			1440	288	287		
Land Space	(Acres)								2.88E-06	1.34E-06		
Lime	(lbs/ton)							22				
Water	(gals/ton)							48	2	0	49.88	
Energy Required	(Btu/ton)	7.12E+04	2.31E+04	2.00E+04	4.28E+05			1.44E+06	2.66E+02	1.67E+02	1.99E+06	
OUTPUTS												
Energy Produced	(Btu/ton)					7.99E+05	3.12E+05	8.50E+06	3.17E+05	0.00E+00	9.92E+06	1
Net Energy	(Btu/ton)	-7.12E+04	-2.31E+04	-2.00E+04	-4.28E+05	7.99E+05	3.12E+05	7.05E+06	3.17E+05	-1.67E+02	7.94E+06	
	(kWh/ton)											
Air Emissions	(lbs/ton)											
Particulates		0.01	4.61E-03					3.31E-02			0.05	
Carbon Monoxide		0.71	0.23					1.14E+00			2.09	
Hydrocarbons		0.07	0.02					NA			0.09	
Nitrogen oxides		0.28	0.09					2.10E+00			2.47	
Air Emissions - L/F	(lbs/ton)											
Methane									2.06	0.00	2.06	
CO2									32.40	0.00	32.40	
CO2-Combustion									30.53	0.00	30.53	
NMOC									0.11	0.00	0.11	
Heavy Metals									NA	NA	0.00	
Add't Air Emissions-RDF	(lbs/ton)											
Total dioxin/furan								3.38E-09			3.38E-09	
SO2								9.86E-01			9.86E-01	
HCl								2.38E-01			2.38E-01	
HF								NA			0.00E+00	
CO2								1.25E+03			1.25E+03	
H2O								8.46E+02			8.46E+02	
Arsenic								ND			0.00E+00	
Cadmium								ND			0.00E+00	
Chromium								7.85E-05			7.85E-05	
Lead								2.88E-04			2.88E-04	
Mercury								4.97E-05			4.97E-05	
Nickel								5.76E-05			5.76E-05	
Zinc								1.53E-04			1.53E-04	
Total Metals								6.26E-04			6.26E-04	

Strategy 8

Technology Description: Curbside MRF + RDF for Direct Firing

TON UNIT: ton of MSW collected

	(units)	Collection Type 1	Collection Type 2	Separation Curbside MRF	Separation Metal Recovery	Use	Use	RDF	Landfill	Landfill	
Water Effluent											
Process Effluent	(gal/ton)										0.00
Leachate	(gal/ton)								11.52	4.94	16.46
COD	(lbs/ton)								2.30E-02	0.00E+00	2.30E-02
TOC	(lbs/ton)								0.00E+00	1.34E-04	1.34E-04
AOX	(lbs/ton)								1.56E-01	NA	1.56E-01
Chloride	(lbs/ton)								1.63E-01	5.74E-01	7.37E-01
Sodium	(lbs/ton)								1.05E-01	1.28E-01	2.33E-01
Potassium	(lbs/ton)								8.64E-02	6.68E-02	1.53E-01
Arsenic									1.24E-02	ND	1.24E-02
Cadmium									4.32E-04	ND	4.32E-04
Chromium									2.35E-02	ND	2.35E-02
Copper									6.19E-03	ND	6.19E-03
Nickel									1.56E-02	ND	1.56E-02
Lead									6.91E-03	ND	6.91E-03
Mercury									8.64E-04	ND	8.64E-04
Zinc									NA	ND	0.00E+00
Heavy Metals	(lbs/ton)								6.58E-02	ND	6.58E-02
Solid Waste	(lbs/ton)			0	0					0.00	
Ash	(lbs/ton)							244.80			244.80
Scrubber Waste								22.32			22.32
Recyclable Products	(lbs/ton)										
newspaper				108							
cardboard				8							
other paper				0							
aluminum				5							
glass				54							
plastic				1							
ferrous metals				5	80						
Total:				180	80						260.00

Strategy 8

Technology Description: Curbside MRF + RDF for Direct Firing

Notes for Strategy 8:

Refer to SRI's Basic Worksheet-Collection for details on collection values.

Refer to SRI's Basic MRF Worksheet for details on MRF and Credit-Recycling values.

Refer to SRI's Basic Landfill Worksheet for details on landfill values.

1) The value for energy produced is not correct for C-Recycling or C-Metals. However, it is correct for net energy.
In order for the spreadsheet to work, the net energy for both C-Recycling and C-Metals are also shown as energy produced.

Strategy 9											
Technology Description: Curbside MRF + RDF for Composting											
TON UNIT: ton of MSW collected											
		Collection	Collection	Separation	Separation	C-Recycling	C-Metals	RDF Composting	Landfill		
	(units)	Type 1	Type 2	Curbside MRF	Metals/Prep						
INPUTS		MSW	Recyclables						MSW	TOTAL	Notes
Percentage		90%	10%	10%	90%	10%	4%	50%	36%		
Feed	(lbs/ton)	1800	200	200	1800	200	80	1000	720		1
Land Space	(Acres)								7.20E-06		
Sludge	(lbs/ton)							250			
Lime	(lbs/ton)										
Water	(gals/ton)							123	5	128.40	
Energy Required	(Btu/ton)	7.12E+04	2.31E+04	2.00E+04	4.28E+05			1.50E+03	6.66E+02	5.44E+05	2
OUTPUTS											
Energy Produced	(Btu/ton)					7.99E+05	3.12E+05	0.00E+00	7.92E+05	1.90E+06	3
Net Energy	(Btu/ton)	-7.12E+04	-2.31E+04	-2.00E+04	-4.28E+05	7.99E+05	3.12E+05	-1.50E+03	7.91E+05	1.36E+06	
	(kWh/ton)										
Air Emissions	(lbs/ton)										
Particulates		0.01	0.00							0.02	
Carbon Monoxide		0.71	0.23							0.94	
Hydrocarbons		0.07	0.02							0.09	
Nitrogen oxides		0.28	0.09							0.38	
Air Emissions - L/F	(lbs/ton)										
Methane									5.16	5.16	
CO2									81.00	81.00	
CO2-Combustion									76.32	76.32	
NMOC								9.80E-02	0.27	0.37	
Heavy Metals									NA	0.00	
Add'l Air Emissions -RDF	(lbs/ton)										
Total dioxin/furan										0.00E+00	
SO2										0.00E+00	
HCl										0.00E+00	
HF										0.00E+00	
CO2											
Antimony										0.00E+00	
Arsenic										0.00E+00	
Cadmium										0.00E+00	
Chromium										0.00E+00	
Lead										0.00E+00	
Mercury										0.00E+00	
Total Metals										0.00E+00	

Strategy 9											
Technology Description: Curbside MRF + RDF for Composting											
TON UNIT: ton of MSW collected											
		Collection	Collection	Separation	Separation	C-Recycling	C-Metals	RDF Composting	Landfill		
	(units)	Type 1	Type 2	Curbside MRF	Metals/Prep						
Water Effluent											
Process Effluent	(gal/ton)									0.00	
Leachate	(gal/ton)							0.00	28.80	28.80	
COD	(lbs/ton)								5.76E-02	5.76E-02	
TOC	(lbs/ton)								0.00E+00	0.00E+00	
AOX	(lbs/ton)								3.89E-01	3.89E-01	
Chloride	(lbs/ton)								4.07E-01	4.07E-01	
Sodium	(lbs/ton)								2.63E-01	2.63E-01	
Potassium	(lbs/ton)								2.16E-01	2.16E-01	
Arsenic	(lbs/ton)								3.10E-02	3.10E-02	
Cadmium									1.08E-03	1.08E-03	
Chromium									5.87E-02	5.87E-02	
Copper									1.55E-02	1.55E-02	
Nickel									3.89E-02	3.89E-02	
Lead									1.73E-02	1.73E-02	
Mercury									2.16E-03	2.16E-03	
Zinc									NA	0.00E+00	
Heavy Metals	(lbs/ton)								1.08E-03	1.08E-03	
Solid Waste	(lbs/ton)							0.00	0.00	0.00	
Recyclable Products	(lbs/ton)								0.00		4
newspaper				108							
cardboard				8							
other paper				0							
aluminum				5							
glass				54							
plastic				1							
ferrous metals				5	80						
Total:				180	80					260.00	
Compost								500.00		500.00	

Strategy 9
Technology Description: Curbside MRF + RDF for Composting
Notes for Strategy 9:

Refer to SRI's Basic Worksheet-Collection for details on two sets of collection values.
Refer to SRI's Basic MRF Worksheet for details on MRF and Metal Recovery, and Credit-Recycling and Credit-Metals values.
Refer to SRI's Basic RDF Composting Worksheet for details on composting values.
Refer to SRI's Basic Landfill Worksheet for details on landfill values.

1) 40-60% of MSW becomes RDF and fed to composting. Reference: Composting facilities noted in Biocycle July 19,1991 pg 50-53.

Strategy 10

Technology Description: Curbside MRF + Landfill + Yard Waste Composting

TON UNIT: ton of MSW collected

INPUTS	(units)	Collection Type 1	Collection Type 2	Collection Type 3	Separation	C-Recycling	Yard Waste Composting	Landfill	TOTAL	Notes
		MSW	Recyclables	Yardwaste	Curbside MRF			MSW		
Percentage		86%	10%	4%	10%	10%	4%	87%		
Feed	2000	1720	200	80	200	200	80	1740		
land					0			1.74E-05	1.74E-05	
Water	(gals/ton)						8.88	13.05	21.93	
Energy Required	(Btu/ton)	7.91E+04	2.31E+04	2.25E+06	2.00E+04		2.72E+03	1.61E+03	2.37E+06	
OUTPUTS										
Energy Produced	(Btu/ton)	0.00E+00			0.00E+00	7.99E+05	0.00E+00	1.91E+06	2.71E+06	1
Net Energy	(Btu/ton)	-7.91E+04	-2.31E+04	-2.25E+06	-2.00E+04	7.99E+05	-2.72E+03	1.91E+06	3.38E+05	
Air Emissions	(lbs/ton)									
Particulates		0.01	4.61E-03	0.45					0.47	
Carbon Monoxide		0.68	0.23	22.48					23.39	
Hydrocarbons		0.07	0.02	2.25					2.34	
Nitrogen oxides		0.27	0.09	8.99					9.36	
L/F+Compost Gas Emissions	(lbs/ton)									
Methane	(lbs/Ton)							12.47	12.47	
CO2	(lbs/ton)							195.75	195.75	
CO2 Combustion								184.44	184.44	
NMOC								0.65	0.65	
Organics							NA		0.00	
Heavy Metals								NA	0.00	
Water Effluent										
Process Effluent	(gal/ton)								0.00	
Leachate	(gal/ton)						0	69.60	69.80	
COD	(lbs/ton)							1.39E-01	1.39E-01	
TOC	(lbs/ton)							0.00E+00	0.00E+00	
AOX	(lbs/ton)							9.40E-01	9.40E-01	
Chloride	(lbs/ton)							9.83E-01	9.83E-01	
Sodium	(lbs/ton)							6.35E-01	6.35E-01	
Potassium	(lbs/ton)							5.22E-01	5.22E-01	
Arsenic	(lbs/ton)							7.48E-02	7.48E-02	
Cadmium								2.61E-03	2.61E-03	
Chromium								1.42E-01	1.42E-01	
Copper								3.74E-02	3.74E-02	
Nickel								9.40E-02	9.40E-02	
Lead								4.18E-02	4.18E-02	
Mercury								5.22E-03	5.22E-03	
Zinc								NA	0.00E+00	
Total Heavy Metals	(lbs/ton)							3.98E-01	3.98E-01	

Strategy 10										
Technology Description: Curbside MRF + Landfill + Yard Waste Composting										
TON UNIT: ton of MSW collected										
		Collection	Collection	Collection	Separation		Yard Waste	Landfill		
Solid Waste	(lbs/ton)						0			
Recyclable Products	(lbs/ton)									
newspaper					108					
cardboard					8					
other paper					0					
aluminum					5					
glass					54					
plastic					1					
ferrous metals					5					
Total:					180				180.00	
Compost							56		56.00	

Strategy 10
Technology Description: Curbside MRF + Landfill + Yard Waste Composting
Notes for Strategy 10:
Refer to SRI's Basic Worksheet-Collection for details on the three types of collection values.
Refer to SRI's Basic MRF Worksheet for details on MRF and Credit-Recycling values.
Refer to SRI's Basic Composting Worksheet for details on composting values.
Refer to SRI's Basic Landfill Worksheet for details on landfill values.

1) The value for energy produced is not correct for C-Recycling. However, it is correct for net energy.
In order for the spreadsheet to work, the net energy for Credit-Recycling is also shown as energy produced.

Strategy 11											
Technology Description: Curbside MRF + Mass Burn + Yard Waste Composting											
TON UNIT: ton of MSW collected											
		Collection	Collection	Collection	Separation	C-Recycling	Composting	MassBurn	Landfill		
	(units)	Type: 1	Type 2	Type 3						TOTAL	Notes
INPUTS		MSW	Recyclables	Yardwaste	Curbside MRF				Monofill		
Percentage		86%	10%	4%	10%	10%	4%	87%	24%		
Feed	2000	1720	200	80	200	200	80	1740	474.15		
land									2.37E-06		
lime								39.15			
Water	(gals/ton)						8.88	21.75	0	30.63	
Sludge	(lbs/ton)									0.00	
Energy Required	(Btu/ton)	7.12E+04	2.31E+04	2.02E+06	2.00E+04		2.72E+03	1.32E+06	2.96E+02	3.46E+06	
OUTPUTS											
Energy Produced	(Btu/ton)	0.00E+00		0.00E+00	0.00E+00	7.99E+05	0.00E+00	8.95E+06	0.00E+00	9.75E+06	1
Net Energy	(Btu/ton)	-7.12E+04	-2.31E+04	-2.02E+06	-2.00E+04	7.99E+05	-2.72E+03	7.64E+06	-2.96E+02	6.29E+06	
Air Emissions	(lbs/ton)										
Particulates		0.01	4.61E-03	4.50E-01						4.68E-01	
Carbon Monoxide		0.68	0.23	2.25E+01						2.34E+01	
Hydrocarbons		0.07	0.02	2.25E+00					0.00E+00	2.34E+00	
Nitrogen oxides		0.27	0.09	8.99E+00						9.36E+00	
Air Emissions-MB	(lbs/ton)										
Particulates								6.09E-02		0.06	
carbon monoxide								5.92E-01		0.59	
hydrocarbons								NA		0.00	
nitrogen oxide								4.17E+00		4.17	
Total dioxin/furan								1.17E-08		0.00	
SO2								2.13E+00		2.13	
HCl								1.22E+00		1.22	
HF								NA		0.00	
CO2								1.44E+03		1.44E+03	
H2O								9.92E+02		9.92E+02	
Metals	(lbs/ton)										
Antimony								NA		0.00E+00	
Arsenic								3.57E-06		3.57E-06	
Cadmium								6.96E-06		6.96E-06	
Chromium								1.65E-05		1.65E-05	
Lead								8.70E-06		8.70E-06	
Mercury								2.00E-04		2.00E-04	
Beryllium								NA		0.00E+00	
Nickel								1.48E-05		1.48E-05	
Zinc								NA		0.00E+00	
Total Metals								2.51E-04		2.51E-04	
L/F Gas Emissions	(lbs/ton)										
Methane	(lbs/Ton)								0.00	0.00	
CO2	(lbs/ton)								0.00	0.00	
Others- Chlorides	lbs/Ton								0.00	0.00	
Heavy Metals	(lbs/Ton)								0.00	0.00	

Strategy 11											
Technology Description: Curbside MRF + Mass Burn + Yard Waste Composting											
TON UNIT: ton of MSW collected											
	(units)	Collection Type: 1	Collection Type 2	Collection Type 3	Separation	C-Recycling	Composting	MassBurn	Landfill	TOTAL	Notes
Organics							NA		NA	0.00	
Water Effluent											
Process Effluent	(gal/ton)							0		0.00	
Leachate	(gal/ton)						0		8.77	8.77	
COD	(lbs/ton)								0.00E+00	0.00E+00	
TOC	(lbs/ton)								2.37E-04	2.37E-04	
AOX	(lbs/ton)								NA	0.00E+00	
Chloride	(lbs/ton)								1.02E+00	1.02E+00	
Sodium	(lbs/ton)								2.28E-01	2.28E-01	
Potassium	(lbs/ton)								1.19E-01	1.19E-01	
Arsenic									ND	0.00E+00	
Cadmium	(lbs/ton)								ND	0.00E+00	
Chromium									ND	0.00E+00	
Copper									ND	0.00E+00	
Nickel									ND	0.00E+00	
Lead									ND	0.00E+00	
Mercury									ND	0.00E+00	
Zinc									ND	0.00E+00	
Total Heavy Metals									ND	0.00E+00	
Solid Waste	(lbs/ton)										
ash								435.00		435.00	
Scrubber waste								39.15		39.15	
Recyclable Products	(lbs/ton)										
newspaper					108						
cardboard					8						
other paper					0						
aluminum					5						
glass					54						
plastic					1						
ferrous metals					5						
Total:					180					180.00	
Compost							56			56.00	

Strategy 11
Technology Description: Curbside MRF + Mass Burn + Yard Waste Composting
Notes for Strategy 11:
Refer to SRI's Basic Worksheet-Collection for details on the three types of collection values.
Refer to SRI's Basic MRF Worksheet for details on MRF and Credit-Recycling values.
Refer to SRI's Basic Composting Worksheet for details on composting values.
Refer to SRI's Basic Mass Burn Worksheet for details on mass burn values.
Refer to SRI's Basic Landfill Worksheet for details on monofill values.

1) The value for energy produced is not correct for C-Recycling. However, it is correct for net energy.
In order for the spreadsheet to work, the net energy for Credit-Recycling is also shown as energy produced.

Strategy #12

Technology Description: RDF production for cofiring with coal

TON UNIT: ton of MSW collected

		Collection Type 1 MSW	Separation Metals/Prep.	Recycling (Credit-Metals)	RDF Cofiring w/ Coal	Landfill MSW	Landfill Monofill	TOTAL	Notes
INPUTS	(units)	100%	100%	4%	80%	16%	15%		
Feed	(lbs/ton)	2000	2000	80		320	297		
Land Space	(Acres)								
RDF	(lbs/ton)				1600			1,600.00	
Coal	(lbs/ton)				0			0.00	
Limestone	(lbs/ton)				25			24.80	
Water	(gals/ton)				53	2	0	55.20	
Energy Required	(Btu/ton)	7.91E+04	4.75E+05		1.61E+06	2.96E+02	1.86E+02	2.16E+06	
OUTPUTS									
Energy Produced	(Btu/ton)			3.12E+05	9.52E+06	3.52E+05	0.00E+00	1.02E+07	1
Net Energy	(Btu/ton)	-7.91E+04	-4.75E+05	3.12E+05	7.91E+06	3.52E+05	-1.86E+02	8.02E+06	
Air Emissions	(lbs/ton)								
Particulates		0.02			1.60E-03			0.02	
Carbon Monoxide		0.79			2.22E+00			3.01	
Hydrocarbons		0.08			NA			0.08	
Nitrogen oxides		0.32			3.14E+00			3.46	
Air Emissions - L/F	(lbs/ton)								
Methane						2.29	0.00	2.29	
CO2						36.00	0.00		
CO2-Combustion						33.92	0.00		
NMOC						0.12	0.00	0.12	
Heavy Metals						NA	NA	0.00	
Add't Air Emissions -RDF	(lbs/ton)								
Total dioxin/furan					4.24E-09			4.24E-09	
SO2					1.47E+00			1.47E+00	
HCl					3.60E-01			3.60E-01	
HF					NA			0.00E+00	
CO2					1.96E+03			1.96E+03	2
H2O					1.04E+03			1.04E+03	
Metals									
Arsenic					ND			0.00E+00	
Cadmium					ND			0.00E+00	
Chromium					1.12E-04			1.12E-04	
Lead					4.24E-04			4.24E-04	
Mercury					8.80E-05			8.80E-05	
Nickel					1.03E-04			1.03E-04	
Zinc					2.63E-04			2.63E-04	
Total Metals					9.90E-04			9.90E-04	

Strategy #12									
Technology Description: RDF production for cofiring with coal									
TON UNIT: ton of MSW collected									
		Collection	Separation	Recycling	RDF	Landfill	Landfill		
		Type 1			Cofiring w/ Coal				
		MSW	Metals/Prep.	(Credit-Metals)		MSW	Monofill	TOTAL	Notes
Water Effluent	(gal/ton)								
Process Effluent	(gal/ton)							0.00E+00	
Leachate	(gal/ton)					12.80	5.49	1.83E+01	
COD	(lbs/ton)					2.56E-02	0.00E+00	2.56E-02	
TOC	(lbs/ton)					0.00E+00	1.48E-04	1.48E-04	
AOX	(lbs/ton)					1.73E-01	NA	1.73E-01	
Chloride	(lbs/ton)					1.81E-01	6.38E-01	8.19E-01	
Sodium	(lbs/ton)					1.17E-01	1.42E-01	2.59E-01	
Potassium	(lbs/ton)					9.60E-02	7.42E-02	1.70E-01	
Arsenic	(lbs/ton)					1.38E-02	ND	1.38E-02	
Cadmium						4.80E-04	ND	4.80E-04	
Chromium						2.61E-02	ND	2.61E-02	
Copper						6.88E-03	ND	6.88E-03	
Nickel						1.73E-02	ND	1.73E-02	
Lead						7.68E-03	ND	7.88E-03	
Mercury						9.60E-04	ND	9.60E-04	
Zinc						NA	ND	0.00E+00	
Heavy Metals	(lbs/ton)					7.31E-02	ND	7.31E-02	
Solid Waste	(lbs/ton)								
Ash	(lbs/ton)				272.00			272.00	
Stabilized Scrubber Sludge					24.80			24.80	
Recyclable Products	(lbs/ton)							0.00	
newspaper			0						
cardboard			0						
other paper			0						
aluminum			0						
glass			0						
plastic			0						
ferrous metals			80						
			80					80.00	

Strategy #12

Technology Description: RDF production for cofiring with coal

Notes for Strategy 12:

Refer to SRI's Basic Worksheet-Collection for details on collection values.
Refer to SRI's Basic MRF Worksheet for details on Metal Recovery and RDF Preparation and Credit-Recycling values.
Refer to SRI's Basic RDF Combustion Worksheet for details on combustion values.
Refer to SRI's Basic Landfill Worksheet for details on landfill and monofill values.

1) The energy produced is not correct for Credit-Metals. However, it is correct for net energy.
In order for the spreadsheet to work, the net energy for Credit-Metals is also shown as energy produced.

Strategy #13								
Technology Description: RDF production for gasification								
TON UNIT: ton of MSW collected								
		Collection	Separation	Credit-Metals	Gasification	Landfill		
		Type 1						
		MSW	Metals/Prep			Monofill	TOTAL	Notes
INPUTS	(units)	100%	100%	4%	96%	21%		
Feed	(lbs/ton)	2000	2000		1920	413		1
Land Space	(Acres)							
O2								
Lime	(lbs/ton)							
Water	(gals/ton)				442	0	441.60	
Energy Required	(Btu/ton)	7.91E+04	4.75E+05		2.21E+06	2.58E+02	2.76E+06	
OUTPUTS								
Energy Produced	(Btu/ton)			3.12E+05	8.26E+06	0.00E+00	8.57E+06	2
Net Energy	(Btu/ton)	-7.91E+04	-4.75E+05	3.12E+05	6.05E+06	-2.58E+02	5.81E+06	
	(kWh/ton)							
Air Emissions	(lbs/ton)							
Particulates		0.02			0.04		0.06	
Carbon Monoxide		0.79			NA		0.79	
Hydrocarbons		0.08			NA		0.08	
Nitrogen oxides		0.32			1.85		2.17	
Subtotal:		1.20			1.90		3.10	
Air Emissions - L/F	(lbs/ton)							
Methane						0.00E+00	0.00E+00	
CO2						0.00E+00	0.00E+00	
CO2-Combustion						0.00E+00	0.00E+00	
NMOC						0.00E+00	0.00E+00	
Heavy Metals						NA	0.00E+00	
Add't Air Emissions -RDF	(lbs/ton)							
Total dioxin/furan					NA		0.00E+00	
SO2					1.52		1.52E+00	
HCl					8.22		8.22E+00	
HF							0.00E+00	
Antimony					NA		0.00E+00	
Arsenic					NA		0.00E+00	
Cadmium					NA		0.00E+00	
Chromium					NA		0.00E+00	
Lead					NA		0.00E+00	
Mercury					NA		0.00E+00	
Total Metals					NA	0.00E+00	0.00E+00	

Strategy #13								
Technology Description: RDF production for gasification								
TON UNIT: ton of MSW collected								
		Collection	Separation	Credit-Metals	Gasification	Landfill		
		Type 1						
		MSW	. Metals/Prep			Monofill	TOTAL	Notes
Water Effluent								
Process Effluent	(gal/ton)						0.00	
Leachate	(gal/ton)					7.64	7.64	
COD	(lbs/ton)					0.00E+00	0.00E+00	
TOC	(lbs/ton)					2.06E-04	2.06E-04	
AOX	(lbs/ton)					NA	0.00E+00	
Chloride	(lbs/ton)					8.88E-01	8.88E-01	
Sodium	(lbs/ton)					1.98E-01	1.98E-01	
Potassium	(lbs/ton)					1.03E-01	1.03E-01	
Arsenic	(lbs/ton)					ND	0.00E+00	
Cadmium						ND	0.00E+00	
Chromium						ND	0.00E+00	
Copper						ND	0.00E+00	
Nickel						ND	0.00E+00	
Lead						ND	0.00E+00	
Mercury						ND	0.00E+00	
Zinc						ND	0.00E+00	
Heavy Metals	(lbs/ton)					ND	0.00E+00	
Solid Waste	(lbs/ton)							
Slag	(lbs/ton)				412.80		412.80	3
Recyclable Products	(lbs/ton)							
newspaper								
cardboard								
other paper								
aluminum								
glass								
plastic								
ferrous metals			80				80.00	

Strategy #13
Technology Description: RDF production for gasification
Notes for Strategy 13:

Refer to SRI's Basic Worksheet-Collection for details on collection values.
Refer to SRI's Basic MRF Worksheet for details on Metal Recovery and RDF Preparation, and Credit-Recycling values.
Refer to SRI's Basic Gasification Worksheet for details on gasification values.
Refer to SRI's Basic Landfill Worksheet for details on monofill values.

1) 100% of MSW is pre-processed of which 4% is diverted for recycling
96% of MSW is processed based on representative examples in operations.
Note that the Andco-Torrax facilities have no pre-separation of MSW.

2) The value for energy produced is not correct for Credit-Metals. However, the net energy is correct.
In order for the spreadsheet to work, the net energy for Credit-Metals is also shown as energy produced.

3) All slag from gasification assumed sent to monofill. Gasification slag reportedly can be used rather than discarded in a landfill.

Strategy 14											
Technology Description: Anaerobic digestion of MSW plus curbside collection of recyclables plus landfill											
TON UNIT: ton of MSW collected											
	(units)	Collection	Collection	Separation	Separation	C-Recycling	C-Metals	Anaerobic D	Landfill		
		Type 1	Type 2	Curbside MRF	Metal Recovery						
INPUTS		MSW	Recyclable						MSW	TOTAL	Notes
Percentage		90%	10%	10%	90%	10%	4%	50%	38%		
Percentage		90%	10%	10%	90%	10%	4%	50%	38%		
Feed	(lbs/ton)	1800	200	200	1800	200	80	1000	720		
Land Space	(Acres)								7.20E-06		
Sludge	(lbs/ton)							460			
Water	(gals/ton)							99	5	104.15	
Energy Required	(Btu/ton)	7.12E+04	2.31E+04	2.00E+04	9.90E+04			3.00E+05	6.66E+02	5.14E+05	
OUTPUTS											
Energy Produced	(Btu/ton)					7.99E+05	3.12E+05	1.98E+06	7.92E+05	3.88E+06	1
Net Energy	(Btu/ton)	-7.12E+04	-2.31E+04	-2.00E+04	-9.90E+04	7.99E+05	3.12E+05	1.68E+06	7.91E+05	3.38E+06	
	(kWh/ton)										
Air Emissions	(lbs/ton)										
Particulates		0.01	0.00							0.02	
Carbon Monoxide		0.71	0.23							0.94	
Hydrocarbons		0.07	0.02							0.09	
Nitrogen oxides		0.28	0.09							0.38	
Air Emissions - L/F	(lbs/ton)										
Methane									5.16	5.16	
CO2									81.00	81.00	
CO2-Combustion									76.32	76.32	
NMOC									0.27	0.27	
Organics								NA		0.00	
Heavy Metals									NA	0.00	
Add't Air Emissions	(lbs/ton)										
Total dioxin/furan										0.00E+00	
SO2										0.00E+00	
HCl										0.00E+00	
HF										0.00E+00	
CO2										0.00E+00	
Antimony										0.00E+00	
Arsenic										0.00E+00	
Cadmium										0.00E+00	
Chromium										0.00E+00	
Lead										0.00E+00	
Mercury										0.00E+00	
Total Metals										0.00E+00	

Strategy 14

Technology Description: Anaerobic digestion of MSW plus curbside collection of recyclables plus landfill

TON UNIT: ton of MSW collected

	(units)	Collection Type 1	Collection Type 2	Separation Curbside MRF	Separation Metal Recovery	C-Recycling	C-Metals	Anaerobic D	Landfill		
INPUTS		MSW	Recyclable						MSW	TOTAL	Notes
Percentage		90%	10%	10%	90%	10%	4%	50%	36%		
Water Effluent											
Process Effluent	(gal/ton)									0.00	
Leachate	(gal/ton)							0.00	28.80	28.80	
COD	(lbs/ton)								5.76E-02	5.76E-02	
TOC	(lbs/ton)								0.00E+00	0.00E+00	
AOX	(lbs/ton)								3.89E-01	3.89E-01	
Chloride	(lbs/ton)								4.07E-01	4.07E-01	
Sodium	(lbs/ton)								2.63E-01	2.63E-01	
Potassium	(lbs/ton)								2.16E-01	2.16E-01	
Arsenic	(lbs/ton)								3.10E-02	3.10E-02	
Cadmium									1.08E-03	1.08E-03	
Chromium									5.87E-02	5.87E-02	
Copper									1.55E-02	1.55E-02	
Nickel									3.89E-02	3.89E-02	
Lead									1.73E-02	1.73E-02	
Mercury									2.16E-03	2.16E-03	
Zinc									NA	0.00E+00	
Heavy Metals	(lbs/ton)								1.65E-01	1.65E-01	
Solid Waste	(lbs/ton)			0	0			0.00	0.00		
Ash	(lbs/ton)										
Recyclable Products	(lbs/ton)								0.00		
newspaper				108							
cardboard				8							
other paper				0							
aluminum				5							
glass				54							
plastic				1							
ferrous metals				5	80						
Total:				180	80					260.00	
Compost								450.00		450.00	2

Strategy 14

Technology Description: Anaerobic digestion of MSW plus curbside collection of recyclables plus landfill

Notes for Strategy 14:

Refer to SRI's Basic Worksheet-Collection for details on the two types of collection values.
Refer to SRI's Basic MRF Worksheet for details on MRF, Metal Recovery, RDP Preparation, and Credit-Recycling and Credit-Metals values.
Refer to SRI's Basic Composting Worksheet for details on anaerobic digestion values.
Refer to SRI's Basic Landfill Worksheet for details on landfill values.

1) The value for energy produced is not correct for C-Recycling or C-Metals. However, it is correct for net energy.
In order for the spreadsheet to work, the net energy for Credit-Recycling and Credit-Metals is also shown as energy produced.

2) Assume compost product is used as compost, not fuel.

3) Does not include metals in sewage sludge that became part of the compost.

Strategy 15														
Technology Description: Curbside separation with mixed recyclables sent to MRF plus yardwaste composting plus RDF for cofiring														
TON UNIT: ton of MSW collected														
	(units)	Collection Type: 1	Collection Type 2	Collection Type 3	Separation	Separation	C-Recycling	C-Metals	Composting	Cofired RDF (w/coal)	Landfill	Landfill	TOTAL	Notes
INPUTS		MSW	Recyclables	Yardwaste	Recycling	Metal/Prep.					Monofill	MSW		
	(lbs/ton)	86%	10%	4%	10%	86%	10%	4%	4%	69%	13%	18%		
Feed	2000	1720	200	80	200	1720			80	1378	255	364		
land											1.28E-06	0.00000364	0.00	
Coal										0.00				
lime										21.33				
Water	(gals/ton)								8.88		0.00	2.73	11.61	
Sludge	(lbs/ton)												0.00	
Energy Required	(Btu/ton)	7.12E+04	2.31E+04	2.25E+06	2.00E+04	4.09E+05			2.72E+03	1.38E+06	1.60E+02	3.37E+02	4.16E+06	
OUTPUTS														
Energy Produced	(Btu/ton)						7.99E+05	3.12E+05		8.19E+06		4.00E+05	9.70E+06	1
Net Energy	(Btu/ton)	-7.12E+04	-2.31E+04	-2.25E+06	-2.00E+04	-4.09E+05	7.99E+05	3.12E+05	-2.72E+03	6.80E+06	-1.60E+02	4.00E+05	5.54E+06	
Air Emissions	(lbs/ton)													
Particulates		0.01	0.00	4.50E-01						3.16E-02			5.00E-01	
Carbon Monoxide		0.68	0.23	2.25E+01						1.09E+00			2.45E+01	
Hydrocarbons		0.07	0.02	2.25E+00						NA			2.34E+00	
Nitrogen oxides		0.27	0.09	8.99E+00						2.00E+00			1.14E+01	
Air Emissions-Add'l	(lbs/ton)													
Total dioxin/furan										3.23E-09			3.23E-09	
SO2										9.43E-01			9.43E-01	
HCl										2.27E-01			2.27E-01	
HF										NA			0.00E+00	
CO2										1.20E+03			1.20E+03	
H2O										6.08E+02			6.08E+02	
Metals	(lbs/ton)													
Arsenic										IND			0.00E+00	
Cadmium										IND			0.00E+00	
Chromium										7.50E-05			7.50E-05	
Lead										2.75E-04			2.75E-04	
Mercury										4.75E-05			4.75E-05	
Nickel										5.50E-05			5.50E-05	
Zinc										1.46E-04			1.46E-04	
SubTotal										5.99E-04			5.99E-04	
L/F Gas Emissions	(lbs/ton)													
Methane	(lbs/Ton)										0.00	2.61	2.61	
CO2	(lbs/ton)										0.00	40.95	40.95	
NMOC	lbs/Ton										0.00	38.58	38.58	
Heavy Metals	(lbs/Ton)										0.00	0.14	0.14	
Organics									NA		NA	NA	0.00	

Strategy 15														
Technology Description: Curbside separation with mixed recyclables sent to MRF plus yardwaste composting plus RDF for cofiring														
TON UNIT: ton of MSW collected														
		Collection	Collection	Collection	Separation	Separation	C-Recycling	C-Metals	Composting	Cofired RDF	Landfill	Landfill		
	(units)	Type: 1	Type 2	Type 3						(w/coal)			TOTAL	Notes
Water Effluent														
Process Effluent	(gal/ton)									14.45			14.45	
Leachate	(gal/ton)								0		4.72	14.56	18.28	
COD	(lbs/ton)										0.00E+00	2.91E-02	2.91E-02	
TOC	(lbs/ton)										1.28E-04	0.00E+00	.1.28E-04	
AOX	(lbs/ton)										NA	1.97E-01	1.97E-01	
Chloride	(lbs/ton)										5.49E-01	2.06E-01	7.54E-01	
Sodium	(lbs/ton)										1.23E-01	1.33E-01	2.55E-01	
Potassium	(lbs/ton)										6.38E-02	1.09E-01	1.73E-01	
Arsenic	(lbs/ton)										ND	1.57E-02	1.57E-02	
Cadmium											ND	5.46E-04	5.46E-04	
Chromium											ND	2.97E-02	2.97E-02	
Copper											ND	7.83E-03	7.83E-03	
Nickel											ND	1.97E-02	1.97E-02	
Lead											ND	8.74E-03	8.74E-03	
Mercury											ND	1.09E-03	1.09E-03	
Zinc											ND	NA	0.00E+00	
Total Heavy Metals											ND	8.32E-02	8.32E-02	
Solid Waste	(lbs/ton)													
Ash										233.92			233.92	
Stabilized Scrubber Sludge										21.33			21.33	
Recyclable Products	(lbs/ton)													
newspaper					108									
cardboard					8.1									
other paper					0									
aluminum					4.5									
glass					54									
plastic					0.9									
ferrous metals					4.5	80								
Total					180	80							280.00	
Compost									0				0.00	

Strategy 15

Technology Description: Curbside separation with mixed recycleables sent to MRF plus yardwaste composting plus RDF for cofiring

Notes for Strategy 15

Refer to SRI's Basic Worksheet-Collection for details on the three types of collection values.

Refer to SRI's Basic MRF Worksheet for details on MRF, Metal Recovery, and RDF Preparation, and Credit-Recycling and Credit-Metals values.

Refer to SRI's Basic Composting Worksheet for details on composting values.

Refer to SRI's Basic Cofired RDF Worksheet for details on RDF values.

Refer to SRI's Basic Landfill Worksheet for details on landfill and monofill values.

1) The value for energy produced is not correct for C-Recycling and C-Metals. However, it is correct for net energy.
In order for the spreadsheet to work, the net energy for Credit-Recycling and C-Metasl is also shown as energy produced.

Transportation Sub-calculations
Basic Collection and Transportation

Transportation Sub-calculations
Source: Palo Alto Community, 1991

Household Refuse Collection

Given: (daily)	
Trucks:	8
Mile/Truck:	7
Tons/Truck:	9
Trip/Day:	1
Mile/Gal:	1.14

Standards:	
Btu/gal:	137000
HC (lbs/btu):	0.000001
CO (lbs/btu):	1.00E-05
NOx (lbs/btu):	0.000004
Particulates (lbs/btu):	0.0000002

Calculations:

(A)	Miles / day =	Trucks / day	x	miles / truck	=	56
(B)	Tons / day =	Trucks / day	x	tons / truck	=	72
(C)	Miles / ton =	(A) / (B)			=	0.78
(D)	Gals / ton =	(C)	x	gals / mile	=	0.68
(E)	Btu / ton =	(D)	x	btu / gal	=	93470
(F)	HC / ton =	(E)	x	HC / btu	=	0.09
(G)	CO / ton =	(E)	x	CO / btu	=	0.93
(H)	NOx / ton =	(E)	x	NOx / btu	=	0.37
(I)	Particulates =	(E)	x	Parts	=	0.02

Notes for Household Refuse Collection:

Household refuse collection refers to the only those trucks dedicated to collecting from a residential community.

Reference: Communication with Palo Alto Sanitation Company, 1991

For information on emissions, see Notes for Commercial Refuse Collection, below.

Transportation Sub-calculations

Commercial Refuse Collection

Given: (daily)	**Trucks** A	B
Trucks:	2	3
Mile/Truck:	7	15
Tons/Truck:	10	10
Trip/day:	2	2
Mile/Gal:	2.5	2.5

Standards:	
Btu/gal:	137000
HC (lbs/btu):	0.000001
CO (lbs/btu):	1.00E-05
NOx (lbs/btu):	0.000004
Particulates (lbs/btu):	0.0000002

Calculations:

(A)1	Miles/day =	Trucks/day	x	miles/truck	x	trip/day =		28	**Truck Type A**
(A)2	Miles/day =	Trucks/day	x	miles/truck	x	trip/day =		90	**Truck Type B**
(A)	Total miles/day =	(A)1	+	(A)2	=		118		
(B)	Tons/day =	Trucks/day	x	tons/truck	x	trip/day =		100	
(C)	Miles/ton =	(A)/(B)			=		1.18		
(D)	Gals/ton =	(C)	x	gals/mile	=		0.47		
(E)	Btu/ton =	(D)	x	btu/gal	=		64664		
(F)	HC/ton =	(E)	x	HC/btu	=		0.06		
(G)	CO/ton =	(E)	x	CO/btu	=		0.65		
(H)	NOx/ton =	(E)	x	NOx/btu	=		0.26		
(I)	Particulates/ton =	(E)	x	Parts/btu	=		0.01		

Transportation Sub-calculations

Notes for Commercial Refuse Collection:

COLLECTION: The energy required for MSW collection depends on a variety of variables: weight of the average pick-up, the distance between residential pick-ups and between commercial pick-ups, the type of trucks used, miles per gallon, the location of the transfer station and/or landfill. Often communities use time/motion studies and models to describe the energy requirements for collection. Reference: wTe Ref 818, 313. However, assumptions used in models often differ, which results in very different conclusions. In most communities where detailed information was available, pick-up of recyclables took longer than municipal solid waste. Due to lack of actual data (versus modeled data), Palo Alto refuse collection (residential and commerciall) was used for Type 1 collection.
This data is good for a community similar to Palo Alto; however, should be customized for other communities.

The calculations for Collection Type 1 in all Strategy Sheets assumes a mix of Household and Commercial Collection.
The respective percentages used are shown in the sub-calculation worksheets for Commercial and Household Collection.
For instructions on changing these percentages, please refer to the Data Base User Guide, page II-2.

EMISSIONS: air emissions for collection were calculated from the EPA standards for engine tests for diesel trucks.
(a standard developed for simulating truck delivery using a mix of city and highway driving, with few stops).
The standard emissions are likely to be less than actual vehicle emissions, as discussed in Volume I.
The emission standards were converted to a Btu basis and multiplied by the truck performance in Btu/ton, and then by a factor of 4 to better account for actual vehicle emissions with a duty cycle with many stops, acceleration, idling, and compaction cycles.

Transportation Sub-calculations

Curbside Recyclables Collection

Given: (daily)		Standards:	
Trucks:	3	Btu/gal:	137000
Mile/Truck:	16.31	HC (lbs/btu):	0.000001
Tons/Truck:	8.5	CO (lbs/btu):	1.00E-05
Trip/day:	1	NOx (lbs/btu):	0.000004
Mile/Gal:	1.14	Particulates (lbs/btu):	0.0000002

Calculations:

(A)	Miles/day =	Trucks/day	x	miles/truck	x	trip/day =		48.93
(B)	Tons/day =	Trucks/day	x	tons/truck	x	trip/day =		25.5
(C)	Miles/ton =	(A)/(B)			=		1.92	
(D)	Gals/ton =	(C)	x	gals/mile	=		1.68	
(E)	Btu/ton =	(D)	x	btu/gal	=		2.31E+05	
(F)	HC/ton =	(E)	x	HC/btu	=		0.23	
(G)	CO/ton =	(E)	x	CO/btu	=		2.31	
(H)	NOx/ton =	(E)	x	NOx/btu	=		0.92	
(I)	Particulates/ton =	(E)	x	Parts/btu	=		0.05	

Transportation Sub-calculations

Notes for Curbside Recycling Collection:

Curbside collection primarily includes collection of newspaper, glass, metal cans from residential communities.

Reference: Communication with Palo Alto Sanitation Company, 1991.

The energy required for curbside pickup depend on a variety of variables: weight of the average pick-up, the participation rate in residential and commercial sectors, the type of products accepted and their density, the type of trucks used (e.g., the number of compartments available, miles per gallon), the location of the MRF. In most communities where detailed information was available, pick-up of recyclables took longer than mixed municipal solid waste. Pick-up of pre-sorted recyclables took two thirds longer than commingled. Reference wTe Ref 265. In addition, usually commingled pick-up requires fewer trucks and fewer separate pick-up trips around the community. Often communities use time/motion studies and models to describe the energy requirements for collection. Reference: wTe Ref 818 and 313. However, assumptions used in the model often differ, which results in very different conclusions. Due to availability of actual data (versus modeled data), Palo Alto recyclables collection was used for Type 2. The data is good for a community similar to Palo Alto; however, should be customized for other communities. In addition, separate runs for cardboard and for debris box pick-up are not included in calculations.

Transportation Sub-calculations

Curbside Cardboard Collection

Given: (daily)			**Standards:**	
Trucks:	1		Btu/gal:	137000
Mile/Truck:	56		HC (lbs/btu):	0.000001
Tons/Truck:	1		CO (lbs/btu):	1.00E-05
Trip/day:	1		NOx (lbs/btu):	0.000004
Mile/Gal:	1.14		Particulates (lbs/btu):	0.0000002

Calculations:

(A)	Miles/day =	Trucks/day	x	miles/truck	x	trip/day =		56
(B)	Tons/day =	Trucks/day	x	tons/truck	x	trip/day =		1
(C)	Miles/ton =	(A)/(B)				=		56
(D)	Gals/ton =	(C)	x	gals/mile		=		49.12
(E)	Btu/ton =	(D)	x	btu/gal		=		6.73E+06
(F)	HC/ton =	(E)	x	HC/btu		=		6.73
(G)	CO/ton =	(E)	x	CO/btu		=		67.30
(H)	NOx/ton =	(E)	x	NOx/btu		=		26.92
(I)	Particulates/ton =	(E)	x	Parts/btu		=		1.35

Notes for Curbside Cardboard Collection:

These data are values for Palo Alto, but were not used in the strategies. Cardboard was included in curbside collecti
Curbside collection primarily includes collection of cardboard material from residential communities.
Reference: Communication with Palo Alto Sanitation Company, 1991.

Transportation Sub-calculations

Curbside Compost Collection

Given: (daily)				Standards:	
Trucks:	8			Btu/gal:	137000
Mile/Truck:	7			HC (lbs/btu):	0.000001
Tons/Truck:	NA	Lbs/6mo:	2184	CO (lbs/btu):	1.00E-05
Trip/day:	1			NOx (lbs/btu):	0.000004
Mile/Gal:	2.5			Particulates (lbs/btu):	0.0000002

Calculations:

(A)	Miles / day =	Trucks / day	x	miles / truck	x	trip / day =		56
(B)	Tons / day =	lbs / month	x	mo / 20 dys	x	ton / 2000 lbs =		0.05
(C)	Miles / ton =	(A) / (B)			=		1025.64	
(D)	Gals / ton =	(C)	x	gals / mile	=		410.26	
(E)	Btu / ton =	(D)	x	btu / gal	=		5.62E+07	
(F)	HC / ton =	(E)	x	HC / btu	=		56.21	
(G)	CO / ton =	(E)	x	CO / btu	=		562.05	
(H)	NOx / ton =	(E)	x	NOx / btu	=		224.82	
(I)	Particulates / ton =	(E)	x	Parts / btu	=		11.24	

Notes for Curbside Compost Collection:

Curbside collection is the collection of compostable material from residential communities.
Reference: Communication with Palo Alto Sanitation Company, 1991.

Basic Mass Burn						
TON UNIT: ton of MSW collected					Mass Burn	
	(units)	Mass Burn			Representative	Notes
INPUTS		< 250 tpd				
		(Modular)				
Raw Materials	(lbs/ton)	2000			2,000.00	
Lime		20-72			*45.00*	1
Water	(gals/ton)	NA			*25.00*	2
Energy Required	(Btu/ton)	*3.43E+06*			1.51E+06	3
OUTPUTS						
Energy Produced	(Btu/ton)	1.03E+07			*1.03E+07*	4
Net Energy	(Btu/ton)	6.86E+06			8.78E+06	
Net Energy	(kWh/ton)	402.58			525.00	5
Air Emissions	(lbs/ton)					
Particulates		0.058			7.00E-02	6
carbon monoxide		4.4			*6.80E-01*	6
hydrocarbons		NA			NA	6
nitrogen oxide		NA			*4.79E+00*	6
total dioxin/furan		NA			1.35E-08	6
SO2		0.27			*2.45E+00*	6
HCl		0.2			*1.40E+00*	6
HF		*4.00E-03*			NA	6
CO2		NA			1.65E+03	7
H2O					*1.14E+03*	7
Antimony		NA			NA	6
Arsenic		*8.70E-05*			4.10E-06	6
Cadmium		*8.70E-05*			8.00E-06	6
Chromium		*8.70E-05*			1.90E-05	6
Lead		NA			1.00E-05	6
Mercury		NA			2.30E-04	6
Beryllium		NA			NA	6
Nickel		NA			1.70E-05	6
Zinc		NA			NA	6
Total Metals		2.61E-04			2.88E-04	
Process Effluent	(gals/ton)	0.00			0.00	8
Solid Waste						9
Ash	(lbs/ton)	420			500.00	
Ash	(Percent of Input)				25%	
Scrubber waste		20-72			*45.00*	1
Products	(lbs/ton)				0.00	10

Basic Mass Burn
Notes for Mass Burn:
NA: Not Analyzed

1) Reference: Calculated from Federal Register 56 February 11, 1991. pg 5519

2) Reference: wTe Appendix A, pg A-73.

3) Reference: for modular Mass Burn. Energy required for modular is 1/3 energy produced. Energy required: wTe A-66 and wTe Appendix A, Attachment 11, Ref 387. Reference: for Mass Burn representative: wTe Reference 799 and Reference 716.
Energy required is 10-14.7% of energy produced.

4) Reference: wTe Reference 387 pg 53. Berenyi, E. and R Gould, 1991 Resource Recovery Yearbook, Directory & Guide. 1991. 5145 Btu/pound.

5) Reference: Appendix A, Attachment 1. 525 ± 75 kWh/ton of MSW.

6) Reference: Compliance Test Report for American Ref-Fuel Company of Hempstead. Radian Corporation, December 1, 1989.

7) Reference: wTe Reference 806. Calculated from values of carbon, hydrogen, and water.

8) Reference: wTe Appendix A, pg 60. Does not include washroom/bathroom water or water in ash. There is little process wastewater that is discharged. It is used in the ash quench tank.

9) Reference: wTe Appendix A, A-20 for 25% ash derived from MSW burned in a modular combustor.
Reference: wTe Appendix A, A-57, A-28 for 25% ash derived from burning MSW (representative mass burn).

10) Recycling credit for ferrous metal is not included in this version of the database. The amount of post-combustion ferrous typically recovered is 2-4% of the incoming waste (D. J. Scanlon, Trash to Energy Plants: A Multidimensional Approach to Solid Waste Management, Resource Recycling April 1991, Pg 76)
The energy saving that comes from recovering the 3% ferrous metal is 0.36 million Btu, which would add 4% to the net energy produced by mass burning a ton of MSW.
(Data is shown in Exhibit III)

Basic RDF Combustion			
TON UNIT: ton of RDF		RDF	
	(units)	Combustion	Note
INPUTS			
Raw Materials	(lbs/ton)	2,000.00	
Lime		31.00	1
Water	(gals/ton)	66.00	2
Energy Required	(Btu/ton)	2.01E+06	3
OUTPUTS			
Energy Produced	(Btu/ton)	1.18E+07	4
Net Energy	(Btu/ton)	9.79E+06	
	(kWh/ton)	455.00	4
Air Emissions	(lbs/ton)		5
particulates		4.60E-02	5
carbon monoxide		1.59	5
hydrocarbons		NA	5
nitrogen oxide		*2.91*	5
dioxin/furan		4.70E-09	5
SO2		1.37	5
HCl		0.33	5
HF		NA	5
CO2		*1.74E+03*	6
H2O		1.18E+03	6
Arsenic		ND	5
Cadmium		ND	5
Chromium		1.09E-04	5
Lead		4.00E-04	5
Mercury		6.90E-05	5
Nickel		8.00E-05	5
Zinc		2.12E-04	5
SubTotal		8.70E-04	
Water Effluent	(gals/ton)	21.00	7
Solid Waste			8
Ash	(lbs/ton)	340.00	
Ash	(%Input)	17%	
Scrubber Waste			9
Waste	(lbs/ton)	*31.00*	
Products	(lbs/ton)	0.00	

Basic RDF Combustion

Notes for RDF Combustion:

NA: Not Analyzed

1) Reference: Federal Register 56 February 11, 1991 pg 5519. Calculated from reference data.

2) Reference: wTe Appendix B pg 134.

3) Reference: wTe Appendix B. For RDF preparation energy required is 27-39 kWh/ton of RDF.
Total energy required is 17.8% of energy produced. The energy required for combustion is total energy required minus RDF preparation.
The energy required for combustion is noted in this worksheet; while the energy for RDF preparation is accounted for in strategy worksheets.

4) Reference: wTe Reference Appendix B pg 5. Energy Produced is 5900 Btu per pound of RDF.
Reference EPRI, Technical Assessment Guide, EPRI P-6587-L Vol 1 September 1989. pg. 7-89. The kWh/ton value calculated using a 15,450 conversion factor (Btu/kWh).
Reference wTe Appendix B-114. Front end processing recovery is 80-90% of the Btu in the MSW.
Reference: wTe Appendix B-114. Dedicated boiler efficiency is 73-78%.

Reference: wTe Reference 387. Range is 455 kWh/ton of RDF ± 100 kWh/ton.

5) Ranges given in RDF Section of report.

6) Reference: wTe Reference 806. Calculated from values of carbon, hydrogen, and water.

7) Reference: Appendix B pg 134. Calculated from 18-66 gals/ton of MSW.

8) Reference: wTe Appendix B-50. Data from the Mid-Connecticut RDF plant.

9) Reference: wTE Reference 26; Federal Register 56 #28 February 11, 1991, pg 5519; and Communication with M. Hartman, ABB.
The scrubber waste is generated from lime slurry injection.

Basic Landfill					
		MSW Landfill		Ash Landfill	Notes
	(units)				
INPUTS					
Raw Materials	(lbs/ton)	2,000.00		2,000.00	
Land Space	(Acres)	2.00E-05		1.00E-05	1
Daily Cover					
Water	(gals/ton)	15.00		0.00	2
					3
Energy Required	(btu/ton)	1.85E+03		1.25E+03	
OUTPUTS					
Energy Produced	(btu/ton)	2.20E+06		0.00E+00	4
Net Energy	(btu/ton)	2.20E+06		-1.25E+03	
Gas Emissions	(lbs/ton)				
Methane	(lbs/Ton)	14.34		0.00	5
CO2	(lbs/ton)	225.00		0.00	6
CO2-Combustion		212.00		0.00	7
NMOC	lbs/Ton	0.75		0.00	8
Heavy Metals	(lbs/Ton)	NA		NA	9
Leachate	(gal/ton)	80.00		37.00	10
COD	(lbs/ton)	0.16			11
TOC	(lbs/ton)			1.00E-03	11
AOX	(lbs/ton)	1.08		NA	11
Chloride	(lbs/ton)	1.13		4.30	11
Sodium	(lbs/ton)	0.73		0.96	11
Potassium	(lbs/ton)	0.60		0.50	11
Arsenic	(lbs/ton)	8.60E-02		ND	12
Cadmium		3.00E-03		ND	12
Chromium		1.63E-01		ND	12
Copper		4.30E-02		ND	12
Nickel		1.08E-01		ND	12
Lead		4.80E-02		ND	12
Mercury		6.00E-03		ND	12
Zinc		NA		ND	12
Total Heavy Metals	(lbs/ton)	0.46		ND	

Basic Landfill

Notes for Landfills:

Notes are listed by landfill technology: MSW landfill, and ash landfill (monofill)

NA: Not analyzed

ND: Not detected

MSW Landfill:

1) Reference: Emcon communication. Assumes 50 foot deep landfill and 1250 lbs/cubic yard for MSW density.
   Reference: California Energy Commission Report, 1991. 50,000 tons of MSW/acre.

2) Reference: wTe Appendix F

3) Reference: wTe Ref 808 and wTe communication for values for compaction and fill covering.

4) Reference: wTe Reference 140, 271, 222, and 478. Energy produced from landfill methane values.
   Reference: Augenstein and Pacey 1991. Energy produced ranges from 1.3-2.4 million Btu/ton.

5) Reference: Augenstein and Pacey 1991. Emissions from a ton of MSW are assumed over 20 years. Emissions ranges from 9-16 lbs/ton of MSW.

6) 288-528 lbs of CO2/ton of MSW with 144-266 lbs of CO2/ton of MSW being biologically generated from landfill.

7) 140-252 lbs of CO2/ton of MSW from combustion of the collected fraction of methane.

8) Reference: Federal Register 56 May 30, 1991. Total Non methane organic compounds is 5 lbs/ton, but 85% is recovered for combustion.

9) Reference: Communication with C. Vollend. Mercury has been detected in landfill gas.

10) Reference: O'Leary and Walsh, Waste Age July 1991 pg 103. Calculated from reference data.
   Of total 80 gals/ton of MSW over 20 years, 11 gals may leach through the liner.

11) Reference: O'Leary and Walsh, Waste Age July 1991 pg 103. Calculated from reference data.

12) Reference: O'Leary and Walsh, Waste Age July 1991. Metal ranges shown in Landfill Section of report.

Ash Landfill (Monofill):

1) Reference: wTe Appendix F. Composition of ash given in Appendix F.

2) Reference: wTe Appendix F and Goodman 1991. Assumes 50 foot depth and 2700 lbs/cubic yard.

3) Reference: wTe Ref 808 and wTe communication. Values for compaction and fill covering.
   Reference: Exhibit 5. The range for operation of landfill is 90,000-230,000 Btu/ton.

4) No energy produced.

5) No studies to indicate emissions.

6) No studies to indicate emissions.

7) No studies to indicate emissions.

8) No studies to indicate emissions.

Basic Landfill

9) No studies to indicate emissions.

10) Reference: O'Leary and Walsh, Waste Age July 1991 pg 103. Proportioned from landfill leachate using density ratio (1250/2700 lbs/cubic yard).

11) Reference: H. Roffman, Woodburn MWC Ash Study, Used the average of the range. This approach overstates the releases of heavy metals as discussed in the text.

12) Reference: H. Roffman. Range located in Landfill Section of report.

Basic MRF									
TON UNIT: ton of recycables collected		Ton of Recyclables	Ton of MSW	Ton of Metals	Ton of Recyclables	Ton of MSW	Ton of Metals		
	(units)	Separation	Separation	Separation	Credits-Recycling	Credits-Recovery	Credits-Metals		Notes
		Curbside MRF	Mixed MRF	Metals/Prep.					
INPUTS		100%	100%	100%	90%	20%	100%		
Raw Materials	(lbs/ton)								
Land	(Acres)								
Water	(gals/ton)	-							
Energy Required	(Btu/ton)	*2.00E+05*	*1.10E+05*	4.75E+05					1
OUTPUTS									
Energy Produced	(Btu/ton)	-	-	-					
Net Energy	(Btu/ton)	-2.00E+05	-1.10E+05	-4.75E+05	7.99E+06	1.93E+06	7.80E+06		2
Air Emissions	(lbs/ton)								3
particulates									
carbon monoxide									
hydrocarbons									
nitrogen oxides									
Solid Waste		200	1600	0					4
Products									5
newspaper		1080	183						
cardboard		81	37						
other paper		0	123						
aluminum		45	3						
glass		540	19						
plastic		9	16						
ferrous metals		45	19	2000					

Basic MRF

Definitions: M Recycling is a Materials Recycling Facility (often called a MRF) which accepts and processes recyclables from curbside pick-up.
M Recover is a Materials Recovery Facility (also often called a MRF or mixed-waste MRF) which separates materials from MSW.
Metals/Prep. is a Resource Derived Fuel (RDF) Preparation process in which metals are picked out of MSW and the remaining MSW is prepared, e.g., shredded, for the RDF process.

Credits-Recycling is production savings from using the recycled materials collected from M Recycling. Details on notes.
Credits-Recover is production savings from using the recycled materials collected from M Recover.
Credits-Matals is production savings from using the metals collected from Metals/Prep..

Notes:

1) MRF: In general, all MRFs use manual labor for much of the picking and sorting of recyclables. Energy requirements greatly depend on the level of manual activities, the type of products accepted, and the secondary markets for each material. The use of material in secondary markets impacts the degree of sorting and level of material quality required. Generally, low technology MRFs ere used for less than 100 ton per day and for inputs with over 50% pre-sorted recyclables. Otherwise, high technology MRFs are used. Reference wTe Ref 386. For a low technology MRF, energy required is about 90,000 Btu/ton, and for a high technology MRF is up to 475,000 Btu/ton. Reference wTe Ref 418 and 181. For the mixed waste MRF, a low-tech MRF without shredder (like Gaston, N. C.) is assumed

Typically technology in a MRF include (181):

Low Technology MRF	High Technology MRF
Conveyors	Conveyors
Screens	Screens
Magnets	Air Classifier
Balers	Shredders
	Magnetic Separators

2) Credits: See Curbside Recycling MRF: Recycling/Production credits, and Mixed MRF: Recycling/Production credits. Sections of Basic MRF Worksheet. This net energy is the sum of production savings from the recycled products. Production savings is the difference between the energy needed to produce a given amount of a basic product from virgin raw material and the energy needed to produce an equal quantity of the same product from recycled raw material, and produced by a MRF. Includes yields of useable material from recycled materials. This value does not include transportation from the MRF to the point of remanufacture. That data is provided in Exhibit III.

3) MRF: No data is available on air emissions from different types of MRFs. However, EPA is currently researching the environmental impacts of MRFs. Studies to date indicate that air emission from MRFs are primarily an employee health concern from dust. (Personal communication with wTe and Alliance Technologies, Feb. 1992)

4) M Recycling: Recycling MRFs that accept pre-sorted recyclabes typically create 3-10% solid waste from a ton input; however, Recycling MRFs that accept commingled recyclables create 10-30%. (149) (386) Assumed 10% of inputs becomes solid waste in order to represent a medium technology Recycling MRF. The composition of solid waste generated by a Recycling MRF depends on the feed. For example, if a MRF does not accept plastics but received plastic accidently during pick-up, this plastic would be solid waste. Perhaps this plastic would not be solid waste at a different MRF. For simplication purposes, we ignore these type of possibilities and assume solid waste consists of material unintentionally collected for MRFs such as: contaminated paper/un-useable paper, specialty plastics, sheet glass, miscellanous metals, and food waste remaining in containers.

M Recovery: Recovery MRFs yield as much as 25% recyclabes, leaving 75% for other disposition. Reference: S. Apotheker, Resource Recycling, Vol. 10 #9 pp. 32-45.

5) M Recycling: In the U.S., Recycling MRFs vary in what recyclables they can process. Type and quantities of recyclables depend on several variables: amount of residential and commercial recyclables generated, bottle-bill status, existing private recyclers (e.g., office paper and cardboard recyclers), the number and convenience of drop-off and buy-back centers, and the market for certain recyclable products. Therefore the percentage of products processed at a Recycling MRF can vary. Generally, Recycling MRFs accepted 50-70% newspaper, 20-50% glass, 1-10% aluminum/ferrous metals, 0-2% plastics, and 0-20% cardboard. Reference wTe Ref 386. For this study, assume 60% newspaper, 30% glass, 2.5% aluminum, 2.5% ferrous metals, 0.5% plastics, and 4.5% cardboard for a total of 100%. The actual percentage will vary with each community and should be adjusted from this base case. Whether or not the community is in a bottle bill state is a key variable. In those communities with bottle bills, there may be only 50% of the aluminum and 60% of the glass expected in a non-bottle bill state in MSW or curbside collection. Reference wTe 808 Bottle bills reduce the amount of materials available for curbside recycling. The Tellus study (White, 1990) indicates the reduction of total MSW is about 5% in bottle bill states. Therefore, the overall effectiveness of curbside is less in a bottle-bill state since availability of recyclables to be collected is less.

M Recovery: Recovery MRFs also vary in what recyclables they can process. Type and quantities of recyclables depend on several variables: amount of residential and commercial recyclables generated, bottle-bill status, existing private recyclers (e.g., office paper and cardboard recyclers), the number and convenience of drop-off and buy-back canters, and the market for certain recyclable products.

Basic MRF

Generally, Recovery MRFs separate old newspapers, old corrugated containers, mixed scrap paper, glass containers, plastics (HDPE, PET) metals (non-ferrous and ferrous), wood, and white goods. For a Recovery MRF, assume estimates from Newport Beach MRF. Newport Beach only includes residential waste. Reference: S. Apotheker, Resource Recycling, Vol. 10 #9 pp. 32-45. The actual percentage will vary with each community and should be adjusted from this base case.

Basic MRF
Recycling MRF
Estimated Potential Energy Savings from Recycling Programs

Product	^(1) Potential Energy Savings (mil Btu/ton product)	^(2) Amount Recycled (#/ton recyclable)	^(3) Percentage Recycled (ton product/ton recyclables)	^(4) Total Savings (mil Btu/ton recyclables)
Newspaper	5.2	1080	54%	2.81
Cardboard Boxes	5.2	81	4%	0.21
Other Paper	5.2	0.00	0%	0.00
Aluminum	181	45	2%	4.07
Glass	1.2	540	27%	0.32
Plastics	*88*	9	0.45%	0.40
Ferrous Metals	7.8	45	2%	0.18
TOTAL:		1800		7.99

Notes:
1) Values for newsprint, paperboard,other paper, glass and ferrous metals from Office of Technology Assessment. Materials and Energy from Municipal Waste. 1979, pg 73. Aluminum values from Kirk Othmer Encyclopedia of Chemical Technology Vol 19 pg 975. (3rd Edition, John Wiley & Sons) and plastic values (including PET and HPDE) calculated from SRI plastic recycling studies.
Potential Energy is the difference between the energy needed to produce a given amount of a basic product from virgin raw material and the energy needed to produce an equal quantity of the same product from recycled raw material (including the recycling process and product production, but not transportation energy to the point of remanufacture).
These values account for the yield losts during production of the secondary material. Yield loss estimated to be 20% for paper, 10% for aluminum, 10% for glass, plastics,. and ferrous metals. Values for percentage recycled (#/recyclables) are taken from Basic MRF worksheet, and are based on a ton of recyclables through a Recycling MRF.
Values for percentage recycled (ton product/ton recyclables) is calculated by dividing by 2000.
Total savings per ton of products equals (1) x (3).

Materials Recovery Facility (M Recovery)
Estimated Potential Energy Savings from Materials collected from Recycling Programs

Product	^(1) Potential Energy Savings (mil Btu/ton product)	^(2) Amount Recycled (#/ton recyclable)	^(3) Percentage Recycled (ton product/ton recyclables)	^(4) Total Savings (mil Btu/ton recyclables)
Newspaper	5.2	183	9%	0.48
Cardboard Boxes	5.2	37	2%	0.10
Other Paper	5.2	123	6%	0.32
Aluminum	181	3	0.14%	0.25
Glass	1.2	19	1%	0.01
Plastics	*88*	18	1%	0.70
Ferrous Metals	7.8	19	1%	0.08
TOTAL:		400		[illegible]

Notes:
1) Values for newsprint, paperboard,other paper, glass and ferrous metals from Office of Technology Assessment. Materials and Energy from Municipal Waste. 1979, pg 73. Aluminum values from Kirk Othmer Encyclopedia of Chemical Technology Vol 19 pg 975. (3rd Edition, John Wiley & Sons) and plastic values (including PET and HPDE) calculated from SRI plastic recycling studies. Potential Energy is the difference between the energy needed to produce a basic product from virgin raw material and the energy needed to produce an equal quantity of the same product from recycled raw material (including the recycling process and product production) .
These values account for the yield lost during production with secondary material. Yield lost estimated to be 20% for paper, 10% for alumimun, 10% for glass, plastics, and ferrous metals. Values for percentage recycled (#/recyclables) are taken from Basic MRF worksheet, and are based on a ton of recyclables through a Mixed MRF.
Values for percentage recycled (ton product/ton recyclables) is calculated by dividing by 2000.
Total savings per ton of MSW equals (1) x (3).

Basic MRF
Metals Recovery Facility

This operation occurs as part of RDF preparation. Metal recovery diverts 4% of MSW if a curbside collection program is assumed to be operating .
The percentage would be greater than 4% if a curbside collection program was not pre-collecting some of the metal.

Product	Savings (mil Btu/ton product)	Amount Recycled (#/ton recyclable)	Percentage Recycled (ton product/ton recyclables)	Total Savings (mil Btu/ton recyclables)
Ferrous Metals	7.8	2000	100%	7.80
TOTAL:		2000		7.80

Basic Composting						
TON UNIT: ton of feed						
		Yard Waste		**MSW**	**MSW**	
	(units)	**Windrows**		**In-Vessel**	**Anerobic**	**Notes**
INPUTS					**Digestion**	
Land	**(Acres)**					
Feed		2,000.00		2,000.00	2,000.00	
Sewage Sludge	(lbs/ton)			500.00	920.00	1
Water	(gals/ton)	222.00		246.00	197.50	2
Energy Required	(btu/ton)	*6.80E+04*		*3.00E+03*	*6.00E+05*	3
OUTPUTS						
Energy Produced	(btu/ton)	0.00		0.00	*3.95E+06*	4
Net Energy	(btu/ton)	-6.80E+04		-3.00E+03	3.35E+06	
Air Emissions	(lbs/ton)					5
Organics		NA		*1.96E-01*	NA	
Leachate	(gal/ton)	*0.00*		*0.00*	*0.00*	6
Solid Waste	(lbs/ton)	*0.00*		*0.00*	*0.00*	7
Product	(lbs/ton)	*1,400.00*		*1,000.00*	*900.00*	8
Compost						

Basic Composting

Notes for Composting:

Notes are listed by composting technology: Windrows, In-vessel, and Anaerobic Digestion.
NA: not analyzed

Windrows:

Refer to Volume I, Report Text
Uses yard waste collected from curbside collection.

1) No sludge used in yard composting.

2) Water is in addition to sludge.

3) Reference: wTe Reference 756 (1989)

4) No energy produced

5) Reference: wTe Appendix G. The windrows facilities are un-enclosed operations for which gas analyzers are unavailable, but noxious quantities of odoriferous gases occur if portions of the windrow are allowed to become anaerobic.

6) Reference: wTe Appendix G. Leachate data not reported.

7) Solid waste may be created if the product is screened before sale or packaging. Oversize may be recycled to the composting operation or landfilled.

8) Reference: wTe Reference 463. Compost is either used as a humus compost product or is landfill cover.
Reference: wTe Reference 450. Windrows for MSW via RDF uses compost after aerobic composting or fuel.
Compost quantity is highly variable depending on composition and amount of easily compostable material (e.g., grass compared to bushes).

In-Vessel Composting:

1) Reference: wTe Reference 463, and Appendix H In vessel example. If sludge is added, 25% sludge is added per ton of MSW.

2) Water is in addition to sludge.

3) Reference: wTe Appendix G. pg G-37. Energy required for In-vessel (19.5 kwh/ton of MSW with sludge) does not include RDF preparation.
Energy required for RDF preparation is approximately 27-39 kWh/ton of RDF
This energy is accounted for the strategy worksheet under the RDF preparation.

5) Reference: wTe Appendix G. Volatization of solvents has been estimated from reference data.

6) Reference: D. Bomberger et al. Waste Characterization Study: Assessment of Recyclable and Hazardous Components. For California Waste Management Board. 1987.
Leachate is assumed to be reinjected; however, leachate can be discharged to local sewer systems.
Solvents in MSW are assumed to be volatile. Amounts based on composition studies.

7) Reference: Biocycle July 19, 1991 pg 50-53. 50% of the MSW is diverted to landfill before composting. This is accounted for in the Strategy worksheets.
Reference: Goldstein. Cocomposting Sludge and Yard Waste, Biocycle January 1991.
Assume oversize compost is screened out and reshredded, otherwise, up to 5% could be landfilled.

8) Reference: wTe Reference 463. Compost is either treated as a humus compost product or is landfill cover. In contrast, designs for anaerobic digestion compost may include combustion of compost for energy recovery.
In vessel composting of MSW requires RDF as feed. Compost is used after additional aerobic curing.

Basic Composting

Anaerobic Digestion (RefCoM model):

1) Reference: Biocycle October 20, 1991. pg 42. If sludge is added, 46% of the weight of MSW as sludge is added per ton of MSW.

2) Water is in addition to sludge.

3) Reference: wTe Reference 450. Appendix H (pg H-40). Energy required derived from RefCoM 500tpd plant (design base, not operating)

4) Reference: wTe Reference 450. Appendix H (pg H-40). Energy produced derived from RefCoM 500tpd plant. Does not include energy from incinerating residue.

5) Air emissions have not been reported in literature. They will be small compared to composting and landfill because the gases are collected and used.

6) Leachate is assumed to be reinjected or remain in filtercake ; however, leachate can be discharged to local sewer systems.

7) Reference: wTe Reference 450 pg 410. 45% of solids that enter the digester come out as solid while the other 55% is converted to gas during the process.
55% of the MSW is diverted to landfill.

8) Reference: wTe Reference 450. Compost is either treated as a humus compost product, landfill cover, or combusted for energy recovery.
Reference: wTe Reference 763. New high solids composting products are intended for land applications.

Basic Gasification			
TON UNIT: ton of RDF			
	(units)	Representative	
INPUTS		500MW	Notes
Raw Materials	(lbs/ton)	2,000.00	
RDF		2,000.00	
Lime			
Water	(gals/ton)	460.00	1
Energy Required	(Btu/ton)	2.30E+06	2
OUTPUTS			
Energy Produced	(Btu/ton)	8.60E+06	3
Net Energy	(Btu/ton)	6.30E+06	3
Air Emissions	(lbs/ton)		4
particulates		4.60E-02	
carbon monoxide		NA	
hydrocarbons		NA	
nitrogen oxide		1.93E+00	
dioxin/furan		NA	
dioxin		NA	
furan		NA	
SO2		1.58E+00	5
HCl		8.56E+00	5
HF			
CO2			
Metals	(lbs/ton)	NA	
Arsenic		NA	
Cadmium		NA	
Chromium		NA	
Copper		NA	
Nickel		NA	
Lead		NA	
Mercury		NA	
Water Effluent	(gals/ton)		
Solid Waste	(lbs/ton)		6
Slag		430.00	
Products	(lbs/ton)	0.00	

Basic Gasification
Notes:

NA: not analyzed.

1) Water is needed as steam to react with the MSW to form gas.

2) References: wTe Appendix A pg A-66. Gasification plant located overseas. Energy required for gasification not including RDF preparation.
Based on 4500 Btu/pound of RDF. Note: For a good comparison to U.S. MSW, 5900 Btu/pound, not 4500 Btu/pound, should be used.

3) References: wTe Appendix A pg A-66. Net Energy is 70-80% of Btu value of the MSW.
The derived energy values were calculated from two facilities: 1) Union Carbide's 150 tpd, oxygen injected, Chichibu Plant, Japan (wTe app D, pg16) and 2) Greve, Italy fluid bed gasification plant (wTe app D, pgs D-19, D-20).

4) References: wTe Appendix D Table D-15 pg D-45. Chichibu City Facility
Gases can be scrubbed to remove acid components. Gases are used to operate plant and generate electricity for export, but are not exported. .
Electricity is generated and exported.

5) References: wTe Appendix D: SO2 values were reported from Funabashi City Facility which was completed in 1981 and has a de-NOx reactor.
Other emissions controls used at this facility are unknown.
In these older studies emissions were not well measured, therefore the actual emissions are higher than these values imply.

6) References: wTe Appendix D Figure D-15 (pg D-45) and D-17 (pg D-46).
In these older studies emissions were not well measured, therefore the actual emissions are higher than these values imply.

Basic Coal/RDF Cofire			
TON UNIT: ton of RDF			
	(units)	Representative	Note
INPUTS		500MW	
Raw Materials	(lbs/ton)		
Coal			1
RDF		2,000.00	
Limestone		31.00	2
Water	(gals/ton)	66.00	3
Energy Required	(Btu/ton)	2.01E+06	4
OUTPUTS			
Energy Produced	(Btu/ton)	1.19E+07	5
Net Energy	(Btu/ton)	9.89E+06	
Air Emissions	(lbs/ton)		
particulates		2.00E-03	6
carbon monoxide		2.78	6
hydrocarbons		NA	6
nitrogen oxide		3.93	6
dioxin/furan		5.30E-09	6
SO2		1.84	6
HCl		0.45	6
HF		NA	6
CO2		2.45E+03	7
H2O		1.30E+03	7
Metals	(lbs/ton)		
Arsenic		ND	6
Cadmium		ND	6
Chromium		1.40E-04	6
Lead		5.30E-04	6
Mercury		1.10E-04	6
Nickel		1.29E-04	6
Zinc		3.29E-04	6
SubTotal		1.24E-03	6
Process Effluent	(gals/ton)	21.00	8
Solid Waste	(lbs/ton)		
Ash		340.00	9
Bottom ash			
Stabilized Scrubber Sludge		31.00	10
Recyclable Products	(lbs/ton)	0.00	

Basic Coal/RDF Cofire
Notes:

1) The quantity of coal is 4.9 x greater than RDF. Reference: wTe Appendix B.
9800 lbs is the quantity of coal per ton of RDF in cofiring.

2) Reference: Federal Register 56 February 11, 1991 pg 5519. Calculated from reference data.
Note that an additional 1406 lbs of limestone is needed for coal scrubbing.

3) Reference: wTe Appendix B pg 130.

4) Reference: wTe Appendix B. For RDF preparation energy required is 27-39 kWh/ton of RDF.
Total energy required is 17.8% of energy produced. The energy required for combustion is total energy required minus RDF preparation.
The energy required for combustion is noted in this worksheet; while the energy for RDF preparation is accounted for in cofiring strategy worksheets.

5) Reference: wTe Reference Appendix B pg 5. Energy Produced is 5900 Btu per pound of RDF.
Reference EPRI, Technical Assessment Guide, EPRI P-6587-L Vol 1 September 1989. pg. 7-89. The kWh/ton value calculated using a 15,450 conversion factor (Btu/kWh).
Reference wTe Appendix B-112. Front end processing recovery is 80-90% of the Btu in the MSW.
Reference: wTe Appendix B-112. Dedicated boiler efficiency is 73-78%.

See also report section on less common technologies.

6) Ranges given in RDF Section of report.

7) Reference: wTe Reference 806. Calculated from values of carbon, hydrogen, and water.

8) Reference: Appendix B pg 130. Calculated from 18-66 gals/ton of MSW.

9) Reference: wTe Appendix B pg 48. Data from the Mid-Conneticut RDF plant.

10) Reference: wTe Reference 26; Federal Register 56 #28 February 11, 1991, pg 5519; and Private Communication with M. Hartman, ABB.
The scrubber waste is a hypothetical amount that would be generated from lime slurry injection. Note that an additional 4966 lbs of scrubber sludge would be produced from the coal.

Exhibit III

ENERGY REQUIREMENTS FOR TRANSPORTATION OF RECYCLABLES TO REMANUFACTURING FACILITIES

Table III-1 shows the transporation energy requirements for virgin materials compared with those for secondary materials shipped for recycling. The bases for the estimates shown in the table are as follows:

Aluminum Ingot

Transportation energy requirements for raw materials:

> 2.7 x10^6 Btu per net ton of aluminum; 85% is for ocean shipping of ore (total energy required to make aluminum metal is 244 x 10^6 Btu per net ton of aluminum)[1]

Recycling aluminum cans to hot metal for can sheet stock:

> Transportation—0.46 x 10^6 Btu per net ton of product, or 612 miles by rail to a primary smelter (total energy required to make sheet can stock is 8.72 x 10^6 Btu per net ton)[2]

Steel

Transportation of ore pellets, coke, fluorspar, and limestone together:

> 0.46 x 10^6 Btu per net ton of steel from a BOF; 31% is for scrap transported 300 miles (total energy required to make steel in a BOF is 20.28 x 10^6 Btu per net ton)[3]

Making steel in an electric furnace from scrap:

> 0.46 x 10^6 Btu per net ton, assuming transportation of 200 miles; a value of 0.0024 x10^6 Btu per ton-mile was used (total energy required to make steel in an electric furnace is 8.28 x 10^6 Btu per net ton)[4]

Glass

Transportation energy requirements:

> 0.386 x 10^6 Btu per net ton of glass containers (total energy required to make glass is 17.43x10^6 Btu per net ton)[5]

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1 Battelle Columbus Laboratories, "Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing, Phase 4—Energy Data and Flowsheets," NTIS PB-245 759, 1975.

2 C.L. Kusik and C. B. Kenahan, "Energy Use Patterns for Metal Recycling," U. S. Bureau of Mines Information Circular 8781, page 26, 1978.

3 Batelle, *op. cit.*

4 Kusik and Kenahan, *op. cit.*, page 77.

5 SRI International calculations based on Battelle, *op.cit.*

Table III-1
COMPARISON OF TRANSPORTATION ENERGY REQUIREMENTS FOR VIRGIN MATERIALS AND SECONDARY MATERIALS SHIPPED FOR RECYCLING

Material	Transportation Energy (Million Btu/Net Ton)	Share of Total Manufacturing Energy (%)	Source
Glass containers	0.386	2.2	Kusik and Kenahan, 1979
Glass containers, recycled	0.48[a]	2.7	SRI estimate
Steel slab, blast furnace, and BOF	0.46	2.3	Battelle, 1975
Steel sheet electric furnace, 100% scrap	0.46	5.6	Kusik and Kenahan, 1978
Aluminum ingot†	2.7[b]	1.1	Battelle
Recycling aluminum cans to can sheet	0.46	5.3	Kusik and Kenahan, 1978

[a] New glass containers have a limited shipping distance before a new plant is built; a probable range of 200 miles at 0.0024 million Btu per ton-mile was assumed (Battelle, 1975).

[b] Ocean shipping of the bauxite accounts for 85% of the total transportation energy (Battelle, 1975).

Exhibit IV

BACKGROUND DATA FOR CALCULATION OF AIR EMISSIONS FROM MUNICIPAL WASTE COMBUSTORS

This exhibit describes the calculation procedures used for deriving total polychlorinated dibenzo-p-dioxin (PCDD)/polychlorinated dibenzo-furan (PCDF) estimates for the two reference plants, the Mid Connecticut RDF plant and the Hempstead mass burn plant. To use the data to compare strategies, it was necessary to to convert the actual Compliance Test data to the basis of 1 ton of MSW at the curb. Compliance Test results are not reported on that basis or on any basis that permits a direct conversion. It was therefore necessary to make certain assumptions to provide a basis for calculating the values used in the comparisons in this report, and those values are therefore estimates of the true performance of the facilities.

MID CONNECTICUT RDF PLANT

Kilgroe and Brna[1] report dioxin/furan data for the Mid Connecticut RDF plant, which were taken under "slightly derated load conditions." Telephone discussions[2] have confirmed that the reported estimates represent actual measurements of Total PCDD/PCDF. Plant data from other sources were used as available to make the necessary conversions.

The following calculation was used to convert the Kilgroe and Brna data to pounds of Total PCDD/PCDF per ton of MSW:

1 ton MSW x 0.85 (the RDF yield[3]) = tons of RDF

Tons RDF x 2000 (lb/ton) = pounds RDF

Pounds RDF x 0.76 = pounds of dry RDF[4]

Pounds of dry RDF x 0.303 = pounds of carbon[5]

Pounds of carbon ÷ 12 = pound-moles of carbon

Pound-moles of carbon ÷ 0.12 = moles of stack gas[6]

Moles of stack gas x 359 x (298 ÷ 273) = cubic feet of stack gas at 25°C

1 Kilgroe, J. D. and T. G. Brna, 1990. Control of PCDD/PCDF Emissions from Refuse Derived Fuel Combustors, *Chemisphere* 20, 1990, p. 1809.

2 Kilgroe, J. D., and M. Hartman, personal communication with Booker Morey, SRI International, June 22, 1992.

3 The actual Mid Connecticut yield of RDF from MSW is 83%; this report uses 85% because it is closer to the typical yield for RDF plants.

4 That value represents the typical moisture content of RDF [806].

5 That is the typical carbon content assuming the typical carbon content of MSW [806], a residue with a fuel value of 3,000 Btu/lb, and an RDF fuel value of 5,900 Btu/lb [806]. Actual data for Mid Connecticut show a 93% combustible recovery (see Appendix B).

6 Stack gas concentration is adjusted to 12% CO_2 (Kilgroe and Brna, 1990).

Cubic feet of stack gas x 0.02831 = standard cubic meters (SCM) of stack gas

SCM of stack gas x 0.56 = ng/SCM Total PCDD/PCDF

Nanograms/SCM Total PCDD/PCDF ÷ 10^9 = grams of Total PCDD/PCDF[7]

Grams of Total PCDD/PCDF ÷ 454 = pounds of Total PCDD/PCDF = 3.7×10^{-9} pounds per ton of MSW.

HEMPSTEAD MASS BURN PLANT

The Hempstead plant data on Total PCCD/PCDF were reported by Radian Corp.[8] They are based on measurements for Unit 1 running at full capacity. The Radian report includes stack gas flow in standard cubic meters per minute (SCM/min) and stack gas concentration in nanograms per standard cubic meter (ng/SCM).

The following calculation was used to convert the Radian data to pounds of Total PCDD/PCDF per ton of MSW:

2909 SCM/min x 1 ng per standard cubic meter concentration (the mean of 12 observations) = nanograms per minute

Nanograms per minute ÷ 10^9 = grams per minute

Grams per min ÷ 454 = 6.4×10^9 pounds Total PCCD/PCDF per minute.

The three-unit plant has a total capacity of 2,050 tons of MSW per day. The following calculation was used to derive tons of MSW feed per minute and Total PCCD/PCDF for a single unit:

2050 pounds MSW ÷ 3 = 683 pounds per day (capacity of one unit)

683 lb/d ÷ 1440 (min per day) = 0.4745 tons per minute of MSW feed.

Pounds per minute Total PCCD/PCDF divided by tons per minute of MSW = $1.35 \cdot 10^{-8}$ pounds of PCCD/PCDF per ton MSW.

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7 The mean reported by J. D Kilgroe and T.G. Brna (1990).

8 Radian Corp. "Compliance Test Report," Volume 1. December 1989.

Exhibit V

BACKGROUND DATA FOR ENERGY CONSIDERATIONS AND ENVIRONMENTAL RELEASES FOR LANDFILLING, ANAEROBIC DIGESTION, AND COMPOSTING

SANITARY LANDFILL

Landfills are often 1,000 to 15,500 acre-feet in size. Depths are occasionally as low as 40, 50, or 60 feet, but landfills are about 125 feet deep on the average, and some are up to 250 feet deep (CEC, 1991, data table). Local ordinances are the main limitations to heights allowed.

Hazardous Material Content

The average hazardous material content of municipal solid waste, according to studies of California landfills by Bomberger, Lewis, and Valdez (1987), is shown in the following tabulation:

Hazardous Material	Pounds per Ton of MSW
Nonchlorinated hydrocarbons	0.05
Chlorinated hydrocarbons	0.0006
Other organics	0.012
Pesticides	0.0000035
Pigments	0.07
Waste oil	0.05
Car batteries	1.3
Household batteries	0.27

Energy Requirements

The Tellus report (White, 1990) gives 0.69 gallon of gasoline per ton of MSW as the energy required for compaction (i.e., 94,530 Btu/ton). wTe estimated 0.23 gallon of gasoline per ton of MSW for compaction (wTe, personal communication to Buford Holt, SRI International, October 22, 1991). No data on the energy costs for constructing the landfill were found, although extensive financial data are available. For purposes of this analysis, the energy requirements for construction, cover placement, and cover compaction are assumed to be of the same order of magnitude, and the estimate for compaction is used for construction and cover placement as well. The following tabulation shows the energy requirements assumed for the calculations in this analysis:

Landfill Operation	Energy Required (Btu per Ton of MSW)
Construction	31,500–95,000
Operation	
Placement of fill	31,500–95,000
Compaction	31,500–94,500

Landfill Gas

Landfill gas is usually saturated when it enters gas collection systems, and its temperature is usually about 90° Fahrenheit. The major constituents other than water, on a dry weight basis, are methane (57%), carbon dioxide (42%), nitrogen (0.5%), oxygen (0.2%), and hydrogen (0.2%). Trace quantities of alkanes, alkenes, aromatics, chlorocarbons, oxygenated compounds, and other hydrocarbons also occur. These may be present at concentrations as high as 20 ppm on a volume basis, and removal of these components may be required before combustion or sale. The California Energy Commission's Energy Technology Status Report cites a 1984 study by J. R. Pena listing 66 trace organic compounds in landfill gas. Five of these—hexane, ethylbenzene, benzene, chlorobenzene, and napthalene—are listed as hazardous air pollutants in the Clean Air Act Amendments of 1990. Other sources report 100–200 compounds in the gases of individual landfills, and at least 350 compounds have been identified at the part-per-billion or greater level in landfill gas [415].

The following tables show the range of the data found for: (1) the composition of landfill gas; (2) concentrations of trace components; (3) frequency of occurrence and concentration of trace components.

COMPOSITION OF LANDFILL GAS

	Percent (Dry Volume)
Methane	47.5–57
Carbon dioxide	42–47.0
Nitrogen	0.5–3.7
Oxygen	0.2–0.8
Paraffin hydrocarbons	0.1
Aromatic and cyclic hydrocarbons	0.2
Hydrogen	0.1
Hydrogen sulfide	0.01
Carbon monoxide	0.1
Trace gases	0.5

Source: CEC (1991); [271]

CONCENTRATIONS OF TRACE COMPONENTS IN LANDFILL GAS

	Concentration (mg/cubic meter)
Ethane	0.8–48
Ethylene	0.7–31
Propane	0.04–10
Butane	0.3–23
Butylene	1–2
Pentane	0–1
Hexane	3–18
Cyclohexane	2–6
Heptane	3–8
Octane	0.05–75
Nonane	0.05–400
Cumene	0–32
Decane	7–48
Dodecane	2–4
Tridecane	0.2–1
Benzene	0.03–7
Toluene	0.2–615

Source: O'Leary and Walsh, 1991

CONCENTRATIONS OF VOLATILE ORGANIC COMPOUNDS IN LANDFILL GAS

(Parts per Million by Volume)

	Mean	Maximum
Pentane	0.4	5.0
Benzene	1.7	23.0
Dichloromethane	0.9	12.0
Hexane	1.8	28.0
Toluene	9.6	210.0
1,1-Dichloroethlylene	0.1	1.1
1,2-Dichloroethlylene	0.7	3.6
1,1 Dichloroethane	0.4	7.5
m,p-Xylene	3.7	91.0
0-Xylene	1.3	25.0
Ethylbenzene	3.0	54.0
Chlorobenzene	0.4	11.0
Iso-Octane	0.4	4.1
Isopropylbenzene	0.7	28.0
Propylbenzene	0.1	3.5
Napthalene	0.01	0.1
Nonane	0.9	8.1
Trichloroethylene	0.8	8.1
1,1,2-Trichloroethane	0.01	0.1
Tetrachloroethylene	1.3	35.0

Source: [415]

FREQUENCY OF OCCURRENCE AND CONCENTRATIONS OF TRACE COMPONENTS IN LANDFILL GAS SAMPLES

	Frequency (% of 60 Sites)	Concentration (Parts per Billion)
Vinyl chloride	50	690–41,000
Benzene	53	540–6,540
Ethylene dibromide	2	6– ?
Ethylene dichloride	22	23–6,000
Dichloromethane	52	61–59,000
Perchloroethylene	65	21–52,000
Carbon tetrachloride	7	5–2,100
Methyl chloroform	40	13–12,000
Trichloroethylene	60	13–11,000
Chloroform	23	4–3,260

Source: [47]

It is not clear how reliable these estimates are. The 1989 report of the Bay Area Air Quality Management District's efforts to measure landfill gas emissions [47] devotes as much space to recounting the problems associated with the data gathered by the air quality regulators as it does to presenting their findings, which are summarized in the following table.

FREQUENCY OF OCCURRENCE OF TRACE COMPONENTS DURING AMBIENT AIR QUALITY MONITORING ABOVE LANDFILLS

	Frequency (% of 45 sites)	Level of Detection (Parts per Billion)
Vinyl chloride	9	2.0
Benzene	36	2.0
Ethylene dibromide	3	0.5
Ethylene dichloride	8	0.2
Dichloromethane	54	1.0
Perchloroethylene	62	0.2
Carbon tetrachloride	10	0.2
Methyl chloroform	64	0.5
Trichloroethylene	44	0.6
Chloroform	5	0.8

Source: [47]

Water Effluents

The table below shows measured contaminants in water effluents from sanitary landfills. Note that the data on organics from Reference [271] are based on a small sample of five sites that were selected for their potential for having high concentrations of priority pollutants. Also note that many of the compounds were found only once. The researchers looked for all 114 priority pollutants [271].

REPRESENTATIVE DATA ON INORGANICS AND ILLUSTRATIVE DATA ON ORGANICS IN LEACHATE FROM SANITARY LANDFILLS

Parameter	Range (O'Leary and Walsh)	Range [271]
General Properties		
Total alkalinity (as $CaCO_3$)	300–11,500	0–20,850
Biochemical oxygen demand (5-day)	20–40,000	9–54,610
Chemical oxygen demand	500–60,000	0–89,520
Hardness (as $CaCO_3$)		0.22–800
pH (standard units)	4.5–9	1.5–9.5
Suspended solids		6–3,670
Conductivity (μohm/cm)		2,810–16,800
Elements	**Parts per Million**	**Parts per Million**
Aluminum		0.5–41.8
Ammonia		0 -1,250
Arsenic	5–1,600	ND–40
Barium		ND–9.0
Beryllium		ND
Boron		0.42–70
Cadmium	0.5–140	ND–1.16
Calcium	20–1,150	507,200
Chloride	100–5,000	5–4,350
Chromium	30–1,600	ND–22.5
Cobalt	4–950	
Copper	4–1,400	ND–9.9
Cyanide		ND–0.08
Fluoride		0.1–1.3
Iron	3–2,100	0.2–42,000
Lead	8–1,020	ND–6.6
Magnesium	40–1,150	12–15,600
Manganese	0.03–65	ND–678
Mercury	0.2–50	ND–0.16
Nitrite and nitrate		0–10.29
Nickel	20-2,050	ND–1.7
Phenol		0.17–6.6
Phosphorus	0.1–30	0–130
Potassium	10–2,500	2–3,770
Selenium		ND–0.45
Silver		ND–0.24
Sodium	50–4,000	0–8,000

REPRESENTATIVE DATA ON INORGANICS AND ILLUSTRATIVE DATA ON ORGANICS IN LEACHATE FROM SANITARY LANDFILLS (Continued)

Parameter	Range (O'Leary and Walsh)	Range [271]
Sulfate	10–2,500	0–84,000
Zinc	0.03–120	0–1,000
Acid Organics (Priority Pollutants)	**Parts per Billion**	
Phenol		221-5,790
4-Nitrophenol		17
Pentachlorophenol		3
Volatile Organics (Priority Pollutants)	**Parts per Billion**	
Ammonia	30–3,000	
Nitrate	0.1–50	
Nitrite	0–25	
Methylene chloride		106-20,000
Toluene		280-1,600
1,1-Dichloroethane		510-6,300
trans-1,2-Dichloroethene		96-2,200
Ethyl benzene		10-250
Chloroform		14.8-1,300
1,2-Dichloroethane		13-11,000
Trichloroethane		160-600
Chloromethane		170
Bromomethane		170
Vinyl Chloride		61
Chloroethane		170
Trichlorofluoromethane		15
1,1,1-Trichloroethane		2,400
1,2-Dichloropropane		54
1,1,2-Trichloroethane		500
cis-1,1-Dichloropropane		18
Benzene		19500
1,1,2,2-Tetrachloroethane		2102,000
Acrolein		270
Dichlorodifluoromethane		180
Bis(chloromethyl) ether		250
Base-Neutral Organics (Priority Pollutants)	**Parts per Billion**	
Bis(2-ethyl hexyl)phthalate		34-150
Diethylphthalate		43-300
Dibutyl phthalate		12–150
Nitrobenzene		40–150
Isophorone		4,000–16,000
Dimethyl phthalate		30–55
Butyl benzyl phthalate		125–150
Napthalene		19
Chlorinated Pesticides (Priority Pollutants)		

REPRESENTATIVE DATA ON INORGANICS AND ILLUSTRATIVE DATA ON ORGANICS IN LEACHATE FROM SANITARY LANDFILLS (Concluded)

Parameter	Range (O'Leary and Walsh)	Range [271]
Delta-BHC		4.6
PCBs (Priority Pollutants)		
PCB-1016		2.8

Source: O'Leary and Walsh (1991); [271]

ASH MONOFILLS

Mass burning produces about 500 pounds of ash per ton of MSW. The ash consists of 375–425 pounds of bottom ash and 75–125 pounds of flyash per ton.

Energy Requirements

No data on energy requirements for ash monofills were found. Data for MSW landfills were therefore used as the basis for estimates for monofills. The Tellus report (White, 1990) gives 0.69 gallon of gasoline per ton of MSW as the energy required for compaction (i.e., 94,530 Btu/ton). wTe estimated 0.23 gallon of gasoline per ton of MSW for compaction (wTe, personal communication to Buford Holt, SRI International, 10/22/91). No data on the energy costs for constructing the landfill were found, although extensive financial data are available. For purposes of this analysis, the energy requirements for construction, cover placement, and cover compaction are assumed to be of the same order of magnitude, and the estimate for compaction is used for construction and cover placement as well. The following tabulation shows the energy requirements assumed for the calculations in this analysis:

Monofill Operation	Energy Required (Btu per Ton of MSW)
Construction	31,500–95,000
Operation	
Placement of fill	31,500–95,000

No energy use data were found in the literature search. The estimates used for this analysis are only indicative of the approximate magnitude of energy required, and they should be used with caution.

Energy Produced

Ash is the result of complete or essentially complete combustion. It has no fuel value.

Water Effluents

Because annual precipitation in the eastern United States is generally more than 30 and less than 60 inches (Visher, 1954), the expected volumes of leachate should range between 14 and 28 gallons per ton of MSW per year (O'Leary and Walsh, Waste Age, July 1991). These estimates provide only an order-of-magnitude indication; actual volumes are influenced by a number of design parameters. The most current data on leachate composition are provided in Roffman, 1991, and presented in Volume I.

ANAEROBIC DIGESTION OF MSW AND SEWAGE SLUDGE

The data in this subsection are based on the RefCoM demonstration plant (Pompano Beach, Florida), the largest anaerobic digestion facility that was operated in the United States. Data reported by wTe in Appendix H were adjusted to reflect weights per ton of MSW *before* the removal of ferrous metals. Thus, the estimates differ slightly from those shown in Figure H-4 in Appendix H.

Additives

The solids content is based on data for vacuum filter dewatering given in the EPA's "Design Manual: Dewatering Municipal Wastewater Sludges." Use of sewage sludge prevents the need for more than occasional use of phosphorus and nitrogen supplements (see Appendix H, page H-5).

Water

According to estimates based on the RefCoM plant, anaerobic digestion consumes 22–36 net gallons of water per ton of MSW. The process consumes 145–154 gallons of water (1,200–1,280 pounds), but 118–123 gallons of water per ton of MSW is added as part of the feedstock. Altogether, the process requires up to 6,000 gallons of water per day per ton of MSW capacity, but most of that water is recycled. Experimental systems using 35–40% solids rather than 10% solids will reduce water requirements by a factor of 3-4. About 70–75 gallons of water are obtained through the addition of primary sewage sludge, about 48 gallons are added in the MSW (4 gallons of which are lost in preprocessing), and 6 gallons are added as steam (see Figure H-4 in Appendix H). Hypothetical calculations for a RefCoM-like plant imply a water consumption of 100 gallons per ton [814].

Energy Produced

Energy production is estimated at 6.1 million Btu per ton of MSW feedstock. One source [802] indicates energy production of 4,000 Btu per pound of volatile solids and a volatile solids percentage of 91.1%. On that basis, energy production was estimated at 6,096,000 Btu per ton of MSW, which was rounded to three significant digits for this analysis.

Yields are sensitive to operating conditions and are higher at higher operating temperatures. Another source [526], which presents data for the RefCoM facility, gives estimates of 12,500,000 Btu per ton of MSW (see Appendix H). An estimate of 2,266,000,000 Joules per ton was provided by a model of a hypothetical facility similar to the RefCoM plant [450].

Solid Waste

Solid waste data for the RefCoM facility indicate that for each ton of MSW, 728 pounds of materials are removed before anaerobic digestion, usually at a materials recovery facility, and 934 pounds of liquids must also be disposed of. The solids that are sent to a landfill depend on the nature of the feedstock. If refuse-derived fuel is used as feedstock, all the by-products from the digestion step can be combusted and only ash is left.

Hazardous Waste

No data on hazardous waste from anaerobic digestion appear to be available, but the heavy metal content should be similar to that resulting from aerobic composting. For comparison, the following tabulation shows mean concentrations of heavy metals in composts from five aerobic composting facilities:

CONCENTRATIONS OF HEAVY METALS IN COMPOSTS FROM AEROBIC COMPOSTING FACILITIES

Element	Concentration
Cadmium	3.5
Chromium	102
Copper	361
Lead	262
Mercury	3.65
Nickel	44.8
Zinc	823
Total for seven elements	1,600

Source: Appendix G; Hegberg et al., *Biocycle*, February 1991

Exhibit VI

TABLES OF CONTENTS FOR APPENDIXES A–J

Appendixes to this report provide detailed summaries of published reports relevant to the MSW management technologies covered in this study. Those appendixes will be published under separate cover. Copies of the Tables of Contents of those volumes are provided on the following pages.

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Exhibit VII

ENERGY BALANCE FOR PAPER MANUFACTURING AND RECYCLING

Analysis of energy savings for paper manufacture and recycling is complicated because:

- The source of energy for papermaking varies with the kind of paper made; fossil fuels are used in some cases, but waste from papermaking is burned for fuel in others.
- The amount of energy used to remanufacture a paper product varies with the particular product being produced.
- No published data were found on the transportation distances from collection to reuse. Because exports are a major outlet for collected paper, transportation to the point of reuse may be a significant energy use.
- It is not clear how to handle energy savings for waste paper that is exported.
- The recycle content of remanufactured paper varies with the final product, and the percentage of waste paper used for each grade affects the energy savings for remanufacture.
- Some paper products—e.g., cardboard, newspaper—can be recycled many times, but others—e.g., tissues—are not recycled.
- The loss of paper fiber that occurs each time the paper is recycled (e.g., about 10% for making newsprint from old newspapers) affects the total possible energy savings, just as the losses of aluminum affect the ultimate energy savings for remanufacturing beverage cans, as discussed on page 113, Vol 1.
- The kind of energy saved may be an issue. For example, remanufacture of new newsprint from used newspapers does save fossil fuels compared to making newsprint from groundwood, but remanufacture does not save fossil fuel compared to making newsprint from chemical pulps.[1]

This subsection outlines the available information related to these topics and indicates the data that would need to be gathered before quantities of energy saved by remanufacturing paper from waste paper could be reliably estimated.

Paper separated at an MRF is used in a variety of products and exports:

- About 21% of collected cardboard is exported; almost all of the remaining 79% is used to make paperboard (which includes cardboard).
- Uses for old newsprint include exports (28%), remanufactured newsprint (34%), paperboard (29%), and tissue (10%).
- About 50% of mixed paper is used to make paperboard, 35% is exported, and 10% is used for tissue.

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1 R. Edward and J. Metz, API, personal communication, August 1992.

Only the grades of paper that can consume the separated paper from a typical MRF are considered because only those grades affect the energy saved by curbside recycling. Table VII-1 shows the total U.S. consumption of these grades of paper and the sources of raw materials for that paper. The total given for waste paper used in these processes includes paper collected outside the curbside collection system.

Table VII-1
SOURCES OF U.S. PAPER SUPPLIES
(Millions of Tons)

Product	Total U.S. Supply,[2] (million tons)	Waste Paper Used,[3] (million tons)	Mechanical Pulp, (million tons)	Chemical Pulp, (million tons)
Newsprint	13.3	1.5	8	3.8
Paperboard	36.4	14.6	None	21.8
Tissue	5.8	3	None[4]	2.8

The process used for making paper affects the amount and source of energy used. Chemical processes like the Kraft or sulfite process are used to make more than 80% of all new paper and paperboard. Most or all of the energy used to make these chemical pulps and paper comes from burning the wood waste and black liquor by-product. In a number of modern mills, no fossil fuels are required.[1]

Groundwood paper, which is a major source of newsprint, is made by mechanically grinding wood into fibers. About 90–95% of a log can be converted into paper, and little wood or pulping waste is produced. Because the grinding is done by electrical motors and little waste is available to burn for fuel, the power for making groundwood is provided by fossil fuels.

Remanufacture of newsprint from old newspapers also depends on fossil fuels.

New paperboard is primarily Kraft paper, which can be made by an energy-self-sufficient chemical process. Manufacture of recycled paperboard requires fossil energy.

A complete analysis of the energy savings and consumption would require the quantitative data outlined in Table VII-2. No published data at this level of detail were found. Data on energy saved by remanufacturing waste paper is therefore an important research need for a detailed assessment of the energy balance of collection, separation, and recycling of paper as part of an MSW management strategy.

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2 America Paper Institute, 1991 Statistics of Paper, Paperboard and Wood Pulp, 1991.

3 American Paper Institute, 1990 Annual Statistical Summary: Waste Paper Utilization, Paper Recycling Committee, API, June 1991.

4 Roger Bogner, American Paper Institute, personal communication, August 12, 1992.

1 R. Edward and J. Metz, API, personal communication, August 1992.

Table VII-2
ENERGY USE PATTERNS IN MANUFACTURE OF SELECTED PAPER AND PAPERBOARD PRODUCTS

Paper Product	Purchased Fossil Energy (Btu)	Other Energy (Btu)
News, groundwood	Most of total energy required	
News, recycle	Most of total energy required	
Paperboard, new		Most of total energy required
Paperboard, recycle	Most of total energy required	
Tissue, new		Most of total energy required
Tissue, recycle	Most of total energy required	

The energy savings data for manufacturing paper products from virgin timber and used paper are limited and inconsistent. Published estimates of energy savings from using old paper as a feedstock vary from 10 million Btu per ton of paper product to zero.[5] One reason for this variation is that the sources are considering different grades of paper. Another is that some of the sources are concerned only with a savings in fossil fuel use. In this report, a value of 5 million Btu per ton[6] was assumed as the energy savings for using cardboard and old newspaper as feedstocks to make new paper products. Although that figure is consistent with the published literature, it probably significantly overestimates the actual savings of fossil fuels.

A study of newsprint manufacture and remanufacture is underway at Argonne National Laboratory that is intended to identify the assumptions and effects of various system boundaries on the energy balances[7]. Estimates of the overall energy balance, and thus most of the differences between estimates from various sources, may reflect assumptions about what is done with the excess ton of old newsprint if it is not recycled.

Finally, accounting for energy savings from imports of paper—13.1 million tons of paper products (virtually no waste paper is imported)—and exports (6.7 million tons of paper products and 6.5 million tons of waste paper)[8] is another complication for any energy balance analysis. The interpretation of any inventory of energy use and production for paper manufacture and remanufacture will depend on the boundaries of the study and the purpose of the calculation.

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5 OTA, ref [723].
6 OTA, ref [723], Office of Technology Assessment: Materials and Energy from Municipal Waste, 1979.
7 F. Stodolsky, personal communication, September 1, 1992.
8 American Paper Institute, 1991 Statistics of Paper, Paperboard and Wood Pulp, 1991.

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The overall objective of the study in this report was to gather data on waste management technologies to allow comparison of various alternatives for managing municipal solid waste (MSW). The specific objectives of the study were to:

1. Compile detailed data for existing waste management technologies on costs, environmental releases, energy requirements and production, and coproducts such as recycled materials and compost.
2. Identify missing information necessary to make energy, economic, and environmental comparisons of various MSW management technologies, and define needed research that could enhance the usefulness of the technology.
3. Develop a data base that can be used to identify the technology that best meets specific criteria defined by a user of the data base.

Volume I contains the report text. Volume II contains supporting exhibits. Volumes III through X are appendices, each addressing a specific MSW management technology. Volumes XI and XII contain project bibliographies.

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