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RESOURCE RECOVERY PLANT COST ESTIMATES: A COMPARATIVE EVALUATION OF FOUR RECENT DRY-SHREDDING DESIGNS

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by

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RESOURCE RECOVERY PLANT COST ESTIMATES: A COMPARATIVE EVALUATION OF FOUR RECENT DRY-SHREDDING DESIGNS

INTRODUCTION

The recovery of salable material resources from mixed municipal solid waste will generally involve rather complex processing of the raw collected refuse in large, capital-intensive facilities. Although local decisions to implement these large-scale resource recovery plants will probably not be based solely on direct cost considerations, cost comparisons among alternative recovery options as well as between recovery options and conventional waste disposal methods will play an important, if not decisive, role in most community decisions. Resource recovery processing costs will also be a factor at the State and Federal levels of policy formulation. For these and other reasons, it is important that sound data be available in a form useful for comparing alternative projects and design concepts.

Unfortunately, little useful cost information is currently available. As of mid-1975, no full-scale mixed-waste separation plants have been constructed or operated. In the absence of operating data, cost projections must be based on preliminary design cost estimates derived largely from experience with pilot-scale operations and equipment supplier quotations.* Aside from this unavoidable factor, the wide diversity of competing systems and the different methods of cost-accounting and estimating used by different designers make relevant comparisons extremely difficult. In addition, most estimates have been site-specific, reflecting economic factors such as labor rates, operating schedules, and other costing parameters peculiar to local circumstances. Thus, even when available, cost estimates have lacked comparability.

This paper reports the findings of a recent EPA investigation designed to clarify the present state of knowledge about the cost of large-scale, mixed-waste processing plants.[1] Its more narrow objective was to provide more definitive comparative cost estimates for one particular type of mixed-waste processing technology, namely: the production of supplemental boiler fuel via mechanical shredding and air

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*For the U.S. Environmental Protection Agency's most recent status report on the planning of these facilities, see: Hopper, R. E. A nationwide survey of resource recovery activities. Environmental Protection Publication SW-142. [Washington], U.S. Environmental Protection Agency, Jan. 1975. 74 p.

classification of solid waste, similar in concept but larger in scale than EPA's prototype demonstration plant in St. Louis.*[2] The second and broader objective was to achieve an improved perspective on the diverse variables that affect costs--including accounting procedures as well as design assumptions and site-specific costing parameters--and thus to point the direction towards more meaningful estimates in the future.

Following a brief introduction to the primary data sources, estimating methods, and design assumptions, comparative results will be presented for capital investment costs, plant operating and maintenance costs, other special cost factors, product revenues, and a final synthesis of net processing costs for a number of recent shredded-fuel plant designs.

It should be emphasized that the dry-shredded-fuel system is only one of several material and energy recovery technologies currently under development,[3] and that the cost estimates presented in this paper apply only to the specific technology under review and only under the general cost-accounting assumptions enumerated below. Readers are thus cautioned to exercise care in interpreting and applying these cost estimates. Although the estimates themselves are both technology-and time-specific, the accounting framework and many of the procedures used to standardize the diverse costing methods should prove applicable to all type of systems.

GEN~RAL METHODS AND DESIGN ASSUMPTIONS

What the Data Represent

The capital and operating cost estimates presented below are derived from a comparative review of five recent preliminary engineering designs.+ The plant designs selected are typical of improved versions of shredded fuel plants patterned after EPA's St. Louis demonstration. All five versions could be considered in either the medium (750 to 1,000 tons per day) or large (1,200 to 2,000 tons per day) size class by current standards. The first commercial application for a plant of this type is scheduled to start up in 1976.

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*Although generally considered to be in the fuel or energy recovery category, this technology is potentially adaptable to fiber recovery for recycling. It may also sometimes be considered as a first-stage unit in an integrated steam or electric generating facility. In the present study, glass and nonferrous metal recovery subsystems have been excluded from the plant flowsheet in developing the cost and revenue estimates.

+The five design documents selected were chosen from a much larger sample of preliminary design studies and cost proposals for plants of this type. Selection was based on level of costing detail and currency of estimates.

The technical designs themselves have been partially modifed in order to reflect a more standardized flowsheet including: hand-sorting of paper, two-stage shredding (or milling) with one-stage air classification to produce a marketable fuel product, and magnetic separation of ferrous metals. Glass and aluminum recovery components have been excluded from the present standardized flowsheet, although originally included in some of the source designs. In addition, original cost estimates have been "normalized" to adjust for a number of differences among the original design studies in terms of estimating methods, accounting formats, and site-specific cost factors.

The five original plant designs and cost estimates are attributable to the following sources.

1. The National Center for Resource Recovery (NCRR), in an engineering feasibility study (December 1972, Ref. 4) as revised in the Winter of 1973-74 in connection with a request for proposals for a plant to be constructed in New Orleans, Louisiana, (Ref. 5). (The EPA modified version is referred to below as NCRR/EPA).

2. Midwest Research Institute (MRI), in a project performed for the Council on Environmental Quality, completed in the Summer of 1972 (Ref. 6), with estimates updated and revised during the Autumn of 1973. (The modified version referred to below as MRI/EPA).

3. The General Electric Company (GE), in a preliminary plant design under contract to the Department of Environmental Protection, State of Connecticut, completed in the Spring of 1973; hypothetically sited for Hartford, Connecticut, (Ref. 7). (Modified version referred to as GE/EPA).

4 and 5. Two confidential proposals actually submitted to a city in 1974. These two designs have been merged into a composite "Plant X" as a means of preserving the confidentiality of proprietary information. (Referred to as X/EPA).

Before presenting the comparative cost results, further comment on the standard plant design and the issues of normalizing costs is necessary in order to define the scope and meaning of the estimates.

Standardizing the Plant Designs

This involves either adding or subtracting building space and equipment items. The objective is not to achieve a completely standardized plant, but rather to standardize only the basic processing sequence and "product lines" while preserving variations in original design conceptions such as structural plant features, throughput and storage capacities, number of primary process lines, and certain other special characteristics considered important by the original designers. They still represent different (independently produced) design conceptions for the same general type of resource recovery facility.

In order for the cost estimates to be meaningfully comparable, it is desirable to be able to standardize the technical assumptions or design conditions relating to plant "capacity," annual operating schedule, and raw waste input composition. "Capacity" turns out to be an ambiguous variable in current design literature. Differences in specifications regarding assumed number of hours per day and total hours per year for plant operation typically vary among designs of the same nominal "capacity" by a factor of two or more. For present purposes, the rated hourly "design" throughput tonnage is accepted as given by the original source. But it has been assumed that the plants will all operate typically on a full two-shift (16 hours per day) processing schedule as a definition of daily design capacity. For purposes of calculating annual fixed costs per tons, maximum annual capacity is based on an assumed 5,000 hours at average hourly design capacity.*

The estimates presented below also assume a standard, national average raw waste input composition[8, p.10], together with material recovery efficiency factors as follows:

(1) 25 percent efficiency in hand-picking of old news and corrugated paper.

(2) 90 percent efficiency in recovering organic material as fuel.

(3) 90 percent efficiency in recovering the ferrous metal fraction as steel scrap.

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*Five thousand hours is roughly equivalent to 312 days per year (6 days per week times 52 weeks) times 16 hours per day. For a 1,000-ton-per-day plant (62.5 tons per hour times 16 hours per day), this implies a maximum annual capacity of 312,000 tons.

Normalizing the Cost and Revenue Estimates

In addition to technical design and operating features, a very large number of nontechnological variables and costing procedures can also strongly influence the estimates. As far as possible, these variables and procedures have been "normalized" to derive the present estimates.

This means that the original sources' design costs have been recalculated on the basis of standardized price or other costing assumptions. As noted below, a number of special cases have been identified where a factor is both significant and can vary over a wide range. For many of these, alternative calculations are presented to show the particular influence of these variables at both high and low values.

The present section discusses the significance of these individual items and their treatment in the study.

Items Affecting Capital Cost. The following items affect initial capital investment cost and, hence, annualized capital cost per ton.*

(1) Land cost. May or may not involve initial direct financing. May or may not be accounted for explicitly in engineering cost estimates. Could amount to a million dollars or more. Excluded from basic capital cost and included under other special cost items because of extreme variations in treatment by different sources.

(2) Site preparation. Extremely site-specific. Demolition of existing structures could amount to several hundred thousand dollars, and thus has been excluded from the standard capital cost estimates.

(3) Regional construction cost differentials. Direct capital costs typically can vary among cities between 75 percent and 115 percent of the U.S. national average. Plant costs in this paper were adjusted to the national average base using regional construction cost indices.

(4) Indirect construction contractor overheads and fees. May or may not be explicitly included by different estimators. Can by 25 percent or more of direct construction costs. In addition, architectural and engineering fees are typically 6 to 8 percent of direct costs.

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*The conversion of an initial capital investment cost to an annual fixed cost for accounting or debt management purposes is discussed in a later section.

(5) "Contingencies." May or may not be explicitly itemized in the estimates. Included as a hedge against unforeseen circumstances in construction. Not a real cost unless some unforeseen circumstance materializes. "Contingencies" are included in addition to labor and equipment cost escalations *per se*. May be 8 to 15 percent of total plant and equipment costs.

(6) Construction cost escalations. In effect, another type of contingency--estimated cost increases for labor, material, and equipment during construction period. Varies both with length of construction period and annual percentage increase assumed. Differences among estimating factors can cause multi-million dollar differences in capital cost estimates. EPA normalized estimates converted to January 1974 base period, where necessary.

(7) Plant startup and working capital. May or may not be included. EPA estimates normalized at four months of operating costs capitalized with other initial investment.

Items Affecting Operating and Maintenance (O&M) Costs. O&M costs are defined here to include only direct, plant-related labor, parts, materials and supplies, and utilities. Other annual costs are included under other special costs, discussed separately in a later section.

(1) Regional O&M factor price differentials. Operating wage rates can vary regionally by more than ±15 percent of the national average. Electric utility rates can vary by a factor of more than 50 percent geographically; fuel prices per Btu can vary by a factor of three or more. The O&M cost figures in Table 3 reflect such adjustments by converting to U.S. nationwide averages.

(2) O&M cost escalations. Escalated differently by different estimators, usually to first year of plant operation from base date of original quote. Differences in original date, projected startup date, and assumed rates of increases can mean a difference of over 50 percent in total O&M cost estimates among different sources. Standard base date of EPA-normalized estimates is January 1974.

(3) Transport costs. Costs of transporting recovered materials accounted for here either in estimating net selling prices or in other special cost category. In various published sources, they have been included under general capital and O&M accounts or ignored altogether.

Other Special Costs of Operations. Five special cost items have been identified which, under various conditions, can each have values ranging from zero to over $1 per ton of raw waste processed (i.e., $300,000 per year based on a 1,000-TPD plant operating 300 days per year). Such wide possible variations can be either locational or institutional in origin. "High" estimating options are indicated below.

(1) Local property taxes. Resource recovery facilities usually have been viewed in the same category as public disposal sites; property taxes seldom have been included in the cost accounts. Some State and regional systems do include an equivalent payment in lieu of taxes, based on assessed value.* An annual charge of 4 percent on total value of property is taken as a "high" cost factor in the comparisons below.

(2) Residual waste disposal costs. About 20 percent of weight (perhaps 5 to 8 percent of volume) or raw waste input not sold as product by present assumption. If disposed of as waste, a disposal cost of $5 per ton assumed "high" for this type of compact, shredded material (equivalent to $1 per ton of total raw waste input). At the other extreme, glass and aluminum content could make the material marketable.

(3) Non-plant overheads. Chargeable to plant operation for off-site services by either a private or public sector central management agency. Could include bookkeeping, marketing, engineering or other functional services, or general overhead. For extreme comparisons, assume range from zero to $1 per ton.

(4) Management fees (profit). Payable to private operator of a publicly-owned or-leased facility. Zero for a publicly-operated facility. One dollar per ton of waste processed would seem to be a "high" fee (exclusive of corporate overhead expenses).

(5) Shredded product transportation costs. Depending on who pays, could be accounted for as reduction in selling price. Treat as separate item chargeable to shredding plant operation. For plants located adjacent to user's boiler, transport cost can approach zero. A "high" cost for reasonably long distances (25 miles) would be $3 per ton of output material ($2 per ton raw wet input basis). Since this is a very large volume item, significant annual costs are involved.

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*The use of "payments in lieu of taxes" is also a means of reducing local prejudice against the location of a regional facility in a particular city. It is also a partial means of compensating a community for additional implicit costs such as increased truck traffic, noise, etc.

Normalized Product Revenue Estimates. Given raw waste input composition and recovery efficiencies (previously discussed) and assuming that product markets are available, then product revenues will be determined by selling prices, less any relevant discounts and transport costs.

Product selling prices easily constitute the greatest source of uncertainty in the entire resource recovery picture. They exhibit the largest variations among geographic regions at any time, and secondary material prices historically have been subject to extreme fluctuations. Future negotiable prices for recovered fuels and metals are also subject to some additional uncertainties due to technical questions of product performance (quality).*

For these reasons it was decided to develop new "high" and "low" product revenue estimates rather than use those found in the original source documents. The estimated revenue schedules are presented below in Table 1. The basic assumptions and derivations of the values for the three products are summarized in the notes accompanying that table.

The prices for both ferrous and paper are stated as values received by the seller (processing plant) net of all transport charges. Shredded fuel prices, however, are defined net of a power plant firing cost discount (assumed at $2.50 per ton of fuel) but without deducting costs of transporting the shredded fuel to the power plant. As previously noted, because it can be such a large and variable element, the cost of transporting the fuel has been singled out for special mention under the other special costs category.

The net product selling prices are combined in Table 1 with the product-yield assumptions to calculate revenue per ton of total raw waste input. Thus, adding all the "high" product revenue estimates results in a total maximum revenue of $15.85 per ton of waste processed. This contrasts sharply with the minimum total net revenue receivable under the low value assumptions of $3.40 per ton of waste processed.

It should be emphasized that the "high" and "low" estimates represent neither the maximum nor the minimum conceivable under all present or future U.S. circumstances. Rather, they simply represent the results of a combined assessment of assumptions relating to product grading (quality) specifications, current U.S. average fuel prices, and material prices experienced within the past 2 years. The high estimates assume no future increase in prices, but the low values assume that wastepaper and steel scrap prices will not fall very much below their lowest levels of the past 2 years. The worst case would be where no markets exist for the shredded fuel or other product.

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*A more important issue, not dealt with here, is the possible types of long-term contractual arrangements that may be developed with user-industries. These might eventually be able to dampen cyclical price fluctuations and also be able to achieve higher product grade ratings than would otherwise be achievable in the general spot markets.

TABLE 1

NET PRICES RECEIVED PER TON OF PRODUCT
AND REVENUE PER TON OF RAW WASTE PROCESSED:
"HIGH" AND "LOW" ESTIMATES (1974)*

Products	Net Prices Per Ton of Product Output †		Recovered Product As A Percentage of Total Waste Input (wet weight basis)	Net Revenue Per Ton of Total Waste Input	
	"High"	"Low"		"High"	"Low"
Shredded fuel ‡	$15.50	$2.50	67.0%	$10.40	$1.70
Paper §	40.00	20.00	4.0%	1.60	0.80
Ferrous Metal ¶	50.00	12.00	7.7%	3.85	0.90
Totals	-	-	78.7%	$15.85	$3.40

*U.S. Environmental Protection Agency estimates. Office of Solid Waste Management Programs, Resource Recovery Division.

†Prices received by seller net of transport or other discounts.

‡Based on Btu value of shredded fuel at 10 million Btu per ton, 30 percent moisture, less $2.50 per ton estimated firing cost to user. "High" net price based on $18.00 per ton fuel (equivalent to $1.80 per million Btu average U.S. contract price for utility grade residual fuel oil in Spring 1974). "Low" price based on $5.00 per ton fuel (equivalent to coal at $0.50 per million Btu or $11.00 per ton), less $2.50 firing cost.

§Average combined prices of old news and corrugated, F.O.B. recovery plant, assuming buyer pays freight. "High" $40,00 price is U.S. average in Spring, 1974. "Low" $20.00 price is U.S. average in Winter 1972-73. Official Board Markets publication quotes.

¶Average scrap steel grade better than No. 2 Bundle grade, less $10.00 per ton freight paid by seller. Gross "high" price of $60.00, Spring 1974 U.S. average. Gross "low" price of $22.00 is Winter 1973 U.S. average. American Metal Market publication quotes.

COMPARATIVE SUMMARY OF NORMALIZED CAPITAL INVESTMENT COST ESTIMATES

Total Capital Cost

Capital investment costs for the four case study plants in Table 2 reflect both the flowsheet revisions and the cost-estimating revisions previously discussed. Otherwise, they reflect the differences in design-conception of their original design teams.

The normalized capital cost estimates for the standardized plant designs show a much closer grouping of values than do the original capital cost figures. However, remaining differences may still seem surprisingly large to many readers. Thus, estimated total investment cost among the four plants varies by a factor of three, from $5.2 million (NCRR/EPA) to $15.5 million (X/EPA) based on 1974 construction costs. This overall difference is reduced somewhat when account is taken of capacity differences (compare total investment cost per ton of daily design capacity). Thus, on a per ton basis, the X/EPA plant becomes second lowest in capital cost at $9,700 per ton of daily capacity.

Although not all differences can be explained on the basis of available documentation, most of the $8.8 million difference between the normalized GE and NCRR capital cost is explained by technical and architectural design differences. For example, the GE design has two completely independent process lines, considerably more material storage space (a particularly costly item for these plants), a pit-and-crane material feed system, and nearly twice the fully-enclosed building area (exclusive of input and output storage) of the NCRR design.

Annualized Capital Cost

Annual capital cost is estimated on the basis of two alternative fixed charge (capital recovery) rates: a low 10 percent rate to illustrate the public sector finance option, and a high 25 percent rate to illustrate annual capital cost allocation under a private industry financing option. It should be emphasized that the 25 percent private rate includes a built-in private profit return on the equity portion of the original investment. The low 10 percent rate includes only interest and amortization for an investment wholly financed by long-term, tax-free borrowing.

The apparent difference between these two alternative institutional approaches to plant financing is quite substantial--a factor of 2.5 in the amounts. It should be pointed out that part of this difference represents a Federal tax subsidy for local public sector loans, i.e., the tax-free nature of local government bonds.

TABLE 2

NORMALIZED CAPITAL INVESTMENT COST ESTIMATES FOR FOUR DRY-SHREDDED-FUEL PROCESSING PLANT DESIGNS * †

Plant Capacity and Investment Cost Measures	NCRR/EPA	MRI/EPA	GE/EPA	X/EPA
Plant Capacity Factors:				
Number of Process Lines	One	One	Two	Two
Design Tons Per Hour	62.5	62.5	62.5	100
Design Tons per Day (16 Hours)	1000	1000	1000	1600
Design Tons Per Year (5000 Hours)	312,500	312,500	312,500	500,000
Normalized Capital Investment:				
Total:				
1974 (Thousands)	$ 5,200	$11,600	$14,000	$15,500
1976 (Thousands)‡	5,980	13,340	16,100	17,830
Total Per Ton Daily Capacity				
1974 (Thousands)	5.2	11.6	14.0	9.7
1976 (Thousands)	5.98	13.34	16.1	11.14
Annualized Capital Cost:				
@ 10% per year:				
1974 (Thousands)	520	1,160	1,400	1,550
1976 (Thousands)‡	598	1,334	1,610	1,785
@ 25% per year:				
1974 (Thousands)	1,300	2,900	3,500	3,875
1976 (Thousands)‡	1,495	3,335	4,025	4,460
Capital Cost Per Ton Raw Waste Processed ($ 1974 Base)				
@ 10% Capital Charge, and:				
(1) 90% capacity utilization	$ 1.85	$ 4.15	$ 5.00	$ 3.45
(2) 75% capacity utilization	2.20	4.95	5.95	4.15
(3) 60% capacity utilization	2.75	6.10	7.35	5.15
@ 25% Capital Charge, and:				
(1) 90% capacity utilization	4.60	10.35	12.50	8.60
(2) 75% capacity utilization	5.55	12.35	14.90	10.35
(3) 60% capacity utilization	6.85	15.25	18.40	12.90

*Office of Solid Waste Management Programs, Resource Recovery Division. Based on original plant design cost estimates by the National Center for Resource Recovery (NCRR), Midwest Research Institute (MRI), the General Electric Co. (GE), and other proprietary sources ("X").

†All plants utilize two-stage shredding and air classification, with magnetic separation of ferrous material and hand picking of paper. Glass and nonferrous recovery options not included. Shredded fuel transport facilities and land costs not included.

‡1976 values escalated at 1.15 x 1974 values to account for inflation to midpoint of construction period.

Capital Cost Per Ton

Capital cost per ton is shown in Table 2 on the basis of the two alternative fixed charge rates and three alternative capacity-utilization rates. The latter are based on a somewhat arbitrary maximum design capacity utilization of 5,000 hours per year. Ninety percent capacity utilization probably represents a high design target from a practical standpoint. The various lower rates can reflect a combination of an intentionally restricted operating schedule (fewer hours per day or days per week), additional equipment downtime for unscheduled repairs, or restricted throughput rates due to low raw waste deliveries or output market bottlenecks.

Other things being equal, unit capital costs will be about 20 percent higher at a 75 percent capacity rate than at a 90 percent rate, and about 25 percent higher still if the plant utilization rate falls to 60 percent. Overall, the difference between achieving only a 60 percent rate as opposed to a 90 percent rate is a capital cost per ton penalty of 50 percent. As shown in Table 2, this penalty varies in absolute dollar terms from a low of just under $1 per ton (NCRR/EPA at 10 percent capital charge) up to a high of almost $6 per ton for the high capital cost GE/EPA plant (under the 25 percent capital charge rate). At the 10 10 percent charge rate, this factor alone accounts for differences of up to $2 or more per ton for the MRI and GE designs. Even the outwardly small differences of 75 vs. 90 percent or 60 vs. 75 percent capacity utilization result in cost differences of $0.35 to $1.60 per ton for the plants in our sample group. At the higher 25 percent fixed charge rate, the effect of capital utilization rates is magnified 2.5 times.

COMPARATIVE SUMMARY OF NORMALIZED O&M COST ESTIMATES

Table 3 provides a comparison of the O&M cost estimates for the four preliminary designs, adjusted to account for certain design standardizations and revised to reflect 1974 base-year national average labor and utility cost factors.*

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*It should be recalled that O&M costs do not include an item for capital charges (or "capital recovery"). Nor do they, at this point, reflect any adjustments either for dump fees charged to those delivering solid wastes or revenues received from product sales. In other words, they represent only the on-site labor, material, and utility costs of the processing facility.

TABLE 3

NORMALIZED OPERATING AND MAINTENANCE COST ESTIMATES FOR FOUR DRY-SHREDDED-FUEL PROCESSING PLANT DESIGNS*

Plant Capacity and O&M Cost Measures	NCRR/EPA	MRI/EPA	GE/EPA "A"	Plant X
Plant Capacity Factors:				
Number of Process Lines	One	One	Two	Two
Design Tons Per Hour	62.5	62.5	62.5	100
Design Tons per Day (16 Hours)	1000	1000	1000	1600
Design Tons Per Year (5000 Hours)	312,500	312,500	312,500	500,000
Total Annual O&M Costs:				
1974 (Thousands)				
@ 90% Annual Capacity Utilization	$ 1,288	$ 1,330	$ 1,554	$ 2,205
@ 75% Annual Capacity Utilization	1,128	1,175	1,363	1,931
@ 60% Annual Capacity Utilization	1,045	1,083	1,264	1,740
1976+ (Thousands)				
@ 90% Annual Capacity Utilization	1,540	1,596	1,862	2,655
@ 75% Annual Capacity Utilization	1,351	1,410	1,533	2,325
@ 60% Annual Capacity Utilization	1,254	1,302	1,520	2.085
O&M Costs Per Ton Waste Processed:				
$ 1974				
@ 90% Annual Capacity Utilization	$ 4.60	$ 4.75	$ 5.55	$ 4.90
@ 75% Annual Capacity Utilization	4.80	5.00	5.80	5.15
@ 60% Annual Capacity Utilization	5.50	5.70	6.65	5.80
$ 1976 +				
@ 90% Annual Capacity Utilization	5.50	5.70	6.65	5.90
@ 75% Annual Capacity Utilization	5.75	6.00	6.95	6.20
@ 60% Annual Capacity Utilization	6.60	6.85	8.00	6.95

*Office of Solid Waste Management Programs, Resource Recovery Division. Based on original plant design cost estimates by the National Center for Resource Recovery (NCRR), Midwest Research Institute (MRI), the General Electric Co. (GE), and other proprietary sources ("X").

+Inflation of 10 percent per year assumed for two-year escalation factor of 20 percent.

Two features of the resulting normalized O&M cost estimates are worth special attention. The first is the relatively close grouping of the estimates for the different plants. Thus, for a given base year, say 1974, and a given relative operating level (say the 90 percent capacity rate), the unit cost estimates differ by not more than about $1 per ton (20 percent). This represents a surprisingly close agreement among the different sources, especially considering that there is so little real operating experience upon which to base estimates.

The second general conclusion is that if the estimates for the several plant capacity utilization rates are accurate, the unit operating costs are moderately responsive to changes in operating levels. Thus, the O&M cost variation for a given plant over its operating range between 60 and 90 percent of its rated capacity was estimated at about $1 per ton (in 1974 dollars) for all four of the plants. However, the engineering data on which the O&M cost penalties for under-capacity utilization are based are quite sketchy. There are no published estimates or analysis of this relationship, but it warrants more attention.

SUMMARY OF TOTAL AND NET COST ESTIMATES

The final synthesis of cost and revenue estimates is presented in two steps. The first step, summarized in Table 4, combines the three categories of costs (capital, O&M, and other special costs) into a range of total cost estimates for each of the four designs in our sample. The second step combines the total cost and revenue estimates into a set of net cost (or net revenue) results, as illustrated in Table 5.

Total Cost Estimates

In the first part of Table 4, capital costs from Table 2 are added to basic O&M processing costs from Table 3. The resulting "total processing costs" are unique for each of the four preliminary plant designs. Basic processing costs are estimated to range from $6.45 per ton for NCRR/EPA to $10.55 for GE/EPA at the low (10 percent) capital charge and the high (90 percent) utilization rate. At the other extreme (high capital charge and low utilization rate), these basic costs are 90 to 150 percent higher, depending on design.

Total process cost differences among the four plants represent differences within the engineering design community as to the capital and operating resource requirements to process mixed waste at the indicated scales. These are differences remaining after our recalculations to standardize design and costing parameters. Considering the state of technological development, the differences in process cost estimates among the four designs are less than might have been expected. In fact, the differences among plants due to different designers are less than the differences for any given plant due to alternative capital charge and operating rate assumptions.

TABLE 4

SUMMARY OF NORMALIZED COST ESTIMATES FOR FOUR
DRY-SHREDDED-FUEL PROCESSING PLANT DESIGNS*
(Dollars Per Ton of Raw Waste Input, 1974 Cost Base)

Cost Categories	NCRR/EPA 90%+	NCRR/EPA 60%+	MRI/EPA 90%+	MRI/EPA 60%+	GE/EPA 90%+	GE/EPA 60%+	"X"/EPA 90%+	"X"/EPA 60%+
Public Sector Finance Option (@ 10% Annual Capital Charge)								
Capital Cost	1.85	2.75	4.15	6.10	5.00	7.35	3.45	5.15
O&M Cost	4.60	5.50	4.75	5.70	5.55	6.65	4.90	5.80
Subtotal Process Cost	6.45	8.25	8.90	11.80	10.55	14.00	8.35	10.95
Total Other Possible Special Costs‡	5.15	5.65	6.05	7.00	6.40	7.50	5.65	6.40
Total Cost Per Ton	11.60	13.90	14.95	18.80	16.95	21.50	14.00	17.35
Private Sector Finance Option (@ 25% Annual Capital Charge)								
Capital Cost	4.60	6.85	10.35	15.25	12.50	18.40	8.60	12.90
O&M Cost	4.60	5.50	4.75	5.70	5.55	6.65	4.90	5.80
Subtotal Process Cost	9.20	12.35	15.10	20.95	18.05	25.05	13.50	18.70
Total Other Possible Special Costs‡	5.15	5.65	6.05	7.00	6.40	7.50	5.65	6.40
Total Cost Per Ton	14.35	18.00	21.15	27.95	24.45	32.55	19.15	25.10

*Office of Solid Waste Management Programs, Resource Recovery Division. Based on original plant design cost estimates by the National Center for Resource Recovery (NCRR), Midwest Research Institute (MRI), the General Electric Co. (GE), and other proprietary sources ("X").

+Percent of plant capacity utilization.

‡Sum of "high" estimated values for all five of the following other possible costs, including: (1) property taxes at 4.0 percent of total investment; (2) land and unusual site work of $1.6 million at 0.07 per year interest; (3) residual waste disposal at $5.00 per ton waste ($1.00 per raw input ton); (4) shredded fuel transport at $3.00 per ton ($2.00 per raw input ton); and (5) non-plant overhead charges of $1.00 per ton of raw waste processed.

TABLE 5

SUMMARY OF ALTERNATIVE NET REVENUE (COST) CALCULATIONS FOR FOUR PRELIMINARY PLANT DESIGNS
AT TWO ALTERNATIVE CAPACITY UTILIZATION RATES
(Dollars Per Ton of Raw Waste Input, 1974 Cost Basis)*

	NCRR/EPA		MRI/EPA		GE/EPA		"X"/EPA	
	90%	60%	90%	60%	90%	60%	90%	60%
High Revenue Cases:								
Case 1: High Revenue Estimate with Process Cost Only.								
Total Product Revenue	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85
Less. Total Process Cost+	6.45	8.25	8.90	11.80	10.55	14.00	8.35	10.95
Less: Min. Other Special Costs	-----	-----	-----	-----	-----	-----	-----	-----
Equals: Net Revenue	$ 9.40	$ 7.60	$ 6.95	$ 4.05	$ 5.30	$ 1.85	$ 7.50	$ 4.90
Case 2: High Revenue Estimate with Maximum Other Special Costs.								
Total Product Revenue	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85
Less: Total Process Cost+	6.45	8.25	8.90	11.80	10.55	14.00	8.35	10.95
Less: Max. Other Special Costs	5.15	5.65	6.05	7.00	6.40	7.50	5.65	6.40
Equals: Net Revenue (Cost)	$ 4.25	$ 1.95	$ 0.90	($ 2.95)	($ 1.10)	($ 5.65)	$ 1.85	($ 1.50)
Low Revenue Cases:								
Case 3: Low Revenue Estimate with Process Cost Only.								
Total Product Revenue	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40
Less: Total Process Cost+	6.45	8.25	8.90	11.80	10.55	14.00	8.35	10.95
Less: Min. Other Special Costs	----	----	----	-----	-----	-----	----	-----
Equals: Net Revenue (Cost)	($ 3.05)	($ 4.85)	($ 5.50)	($ 8.40)	($ 7.15)	($10.60)	($ 4.95)	($ 7.55)
Case 4: Low Revenue Estimate with Maximum Other Special Costs.								
Total Product Revenue	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40
Less: Total Process Cost+	6.45	8.25	8.90	11.80	10.55	14.00	8.35	10.95
Less: Max. Other Special Costs	5.15	5.65	6.05	7.00	6.40	7.50	5.65	6.40
Equals: Net Revenue (Cost)	($ 8.20)	($10.50)	($11.55)	($15.40)	($13.55)	($18.10)	($10.60)	($13.95)

*Office of Solid Waste Management Programs, Resource Recovery Division. Based on original plant design cost estimates by the National Center for Resource Recovery (NCRR), Midwest Research Institute (MRI), the General Electric Company (GE), and other proprietary sources ("X").

+Sum of capital cost and O&M cost from Table 4. Capital cost based on 10.0 percent annual fixed charge rate (capital recovery).

As previously discussed, the other special cost items may or may not be relevant under particular locational and institutional circumstances. Thus, each of these cost items may have zero values for particular cases, or they each may involve substantial additional annual and per ton expense to the recovery operation. The values included in Table 4 are our EPA "high" cost estimates. They do not necessarily reflect either the particular values or, in some cases, even the same categories of costs estimated in the original design source documents. Rather, they have been applied to all the designs in our sample as an added means of normalizing the estimates for comparative purposes.

Thus, the other special cost elements, taken as a group, can sum up to any value from zero to some significantly higher cost. The maximum value for our comparative cases varies between $5.15 and $7.50 per ton, depending on plant capital cost (a variable in the property tax cost function) and level of capacity utilization.

In the very special case where other special costs are all zero, total processing cost is the only cost to be balanced against product revenues to determine net cost or revenue from plant operation.

Net Revenue or Cost Results

The final step in the cost-estimating procedure is to subtract total cost from product revenues to yield net revenue (profit) or cost results.* Table 5 presents four sets of net cost calculations for each of the four case study designs to show the various combinations of: high revenue with low cost; high revenue with high cost; low revenue with low cost; and low revenue with high cost.

The first two net revenue calculations for each plant represent the low and the high cost possibilities as developed in Table 4 in conjunction with the "high" ($15.85 per ton) total revenue estimate from Table 1. The net revenue line for Case 1 indicates positive net revenues for all plants. Thus, so long as "high" revenues can be combined with costs that do not exceed standard process cost by substantial amounts, all four case study plants appear profitable at the current estimated values under public sector financing. Even when a maximum other special cost sum is charged (Case 2), NCRR/EPA remains profitable at the 60 percent capacity utilization rate, and both MRI and Plant X continue to show net revenue at high utilization rates.

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*Other things being equal, in situations where cost exceeds product revenues, the net cost values may be considered equal to the dump fee required for the facility to break even. Alternatively, one may wish to compare these net cost values against the community's alternative opportunity costs of conventional disposal or other resource recovery options.

For the low revenue ($3.40 per ton) Cases 3 and 4, net positive revenue disappears, even where low costs are involved. Results show net costs of about $3.00 to $7.00 per ton at 90 percent utilization rates and $5.00 to $11.00 at low capacity rates for Case 3. It is noteworthy that the net costs in this line are still generally competitive with landfill costs in many, if not most, highly urbanized areas.

The final "bottom line" (Case 4) represents the worst situation shown with respect to resource recovery--i.e., low revenue combined with highest possible cost for the plant cases presented. Even the results for these worst-case resource recovery alternatives are encouraging because net cost estimates in all cases remain competitive with conventional incineration.

A number of caveats must be made. The first is that the results in Table 5 all assume the low (public sector) 10 percent capital recovery rate. Costs increase under a strict private-enterprise rate of return formulation. However, a privately-financed facility, if well managed and strategically located, could be profitable under some realistic locational and market circumstances. Another point that must be kept in mind is that all the basic cost estimates are themselves subject to substantial possibilities for error. No such plant has yet been constructed or operated, and all costs are based on preliminary design estimates rather than final detail design figures. Further, a serious effort has been made to present costs on a national average basis, and many of our urban areas will have costs at least 10 to 15 percent higher than these estimates on the basis of location alone.

Finally, it should be noted that the present analysis does not evaluate the question of "economies of scale" for plants of different design capacities. Generally, one would expect that, other things being equal, plants smaller than those in the study sample would show higher capital and operating costs per ton than the estimates presented here, and conversely, larger plants might result in somewhat lower unit costs. However, an analysis of economies of scale is beyond the scope of this study, and there has been no definitive quantitative work on this subject to date.

SUMMARY AND CONCLUSIONS

The Environmental Protection Agency has analyzed a number of engineering design conceptions for the next generation of shredded fuel recovery plants based on the St. Louis prototype. Existing cost estimates prepared by engineering consultant and system development companies are not directly comparable with one another because of differences in estimating methods, accounting formats, and location-specific costing factors. Therefore, five recent preliminary design cost studies were normalized to produce comparable cost estimates representative of the degree of consensus within the engineering community.

The results indicate that differences in cost estimates among design conceptions and engineering firms are still quite significant, even after adjustments for location, time, and other nonstandard elements of costing procedure. However, the differences are no greater than might be expected given the present state of technological development and lack of operating commercial prototypes. Indeed, differences in basic capital and operating costs attributable to different technical engineering conceptions are in many respects of less consequence than the differences introduced by the use of alternative costing methods and location-specific cost factors.

Analysis of normalized cost estimates and alternative product selling price projections indicates that potential net cost projections will fall in a very broad range from positive to negative. The results suggest that there could be some favorable cases where operation of this type of processing plant will yield a profit from sales of product, exclusive of dump fees. Intermediate cases--i.e., those which combine either high revenue with high cost or low revenue with low cost--generally appear competitive with current or projected landfill costs in many, if not most, U.S. cities. All low cost (public sector) financing options were at least competitive with conventional municipal incineration, even for the highest cost case study plant.

For a project planning and evaluation standpoint, three conclusions of the analysis bear special emphasis:

1. The relative importance of total revenue and the very large absolute differences between high and low estimates. The most significant aspects of uncertainty relate to the largest volume output, namely, the potential market value of the shredded fuel. Differences between "high" and "low" shredded fuel selling price estimates account for most of the difference between a $16 and a $3 total product revenue per ton of raw waste processed. This difference dwarfs almost all other variable elements of the net cost and revenue estimates.

2. The significance of maintaining high capacity utilization rates. This is evident in the comparisons for individual plants where differences in net cost of $2 to over $4 per ton consistently result for estimates at the 90 percent vs. 60 percent capacity utilization rates. The high cost of failure to maintain high capacity utilization levels underlines the importance of sound planning and high quality management.

3. The cumulative importance of other special cost elements. If costs are divided into three categories as in Table 4, it comes as something of a surprise that other costs can be larger in total than either the standard capital cost or the direct O&M processing cost categories. The potential cumulative effect of these items on the overall net cost picture suggests that they are worthy of considerable attention by planners and designers from a cost minimization standpoint.

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