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A COST ANALYSIS OF MUNICIPAL YARD WASTE COMPOSTING

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INTRODUCTION

Solid waste disposal has become a pressing issue of concern for county and municipal governments throughout North Carolina. As available landfill space diminishes and the cost of siting and building new landfills increases, local authorities are having to grapple with alternative means of meeting the waste disposal challenge. Further complicating matters is recent legislation requiring a 25% reduction in waste entering landfills (and completely banning landfill disposal of yard waste). This has provided impetus for community leaders to explore alternative means of reducing the size of the waste stream entering landfills.

Municipal yard waste composting has emerged as a potentially viable means by which local governments can reduce both the volume of waste and the proportion of the waste stream entering landfills. Yard waste currently comprises 18% of total solid waste generated nationally (EPA, 1992), and many communities have successfully established composting facilities as a component of their integrated solid waste handling strategy. It is essential for communities contemplating a municipal composting facility to have reliable and current information on the likely costs of establishing and operating such facilities. Currently, such information is not readily available.

This research report begins to remedy this information gap by analyzing the costs of building and operating municipal yard waste composting facilities of different sizes and levels of technical sophistication. The detailed cost information reported will enable local authorities to understand how expensive it will be to employ yard waste composting as a part of an integrated solid waste disposal strategy. This information will allow users todecide whether composting makes economic sense, given local fiscal and budgetary constraints. If it does, then comparison of the costs of different composting facilities for a given amount of compostable waste will provide insight into the type of facility that should be constructed.

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Three types of open-windrow composting facilities will be examined: (a) a simple "minimal-tech" system requiring limited labor and mechanical inputs; (b) a "low-tech" system featuring open-air windrows (piles) placed on a paved surface and a front-end loader for turning piles; and (c) a "medium-tech" system that features a paved surface, a windrow turner for turning piles, and screening and shredding equipment to insure uniform consistency of the finished product. Three different waste stream levels will be considered (low, medium, and high) corresponding to localities of different sizes.

This report is organized as follows. The next section presents basic information on composting and the options and tradeoffs involved in the design and day-to-day operation of municipal composting facilities. The third section describes the prototype facilities for which cost estimates are presented. The fourth section outlines the assumptions made in computing the costs of constructing and operating prototype facilities, presents the cost analysis of various types of facilities, and includes summary tables itemizing these costs. The final section summarizes the study's findings and suggests areas for further study. An appendix contains detailed cost estimates for the various prototype facilities considered.

BACKGROUND

Composting is a controlled biological process that uses natural aerobic processes to increase the rate of biological decomposition of organic materials such as leaves, grass clippings, and other yard waste. It is carried out by successive microbial populations that break down organic materials into carbon dioxide, water, minerals, and stabilized organic matter. Five key variables govern the rate and thoroughness of decomposition effected through composting: *(a)* oxygen; *(b)* moisture; *(c)* temperature; *(d)* the ratio of carbon to nitrogen in the material being composted; and *(e)* particle size. Oxygenation is effected either through turning of compost piles or through piping air into piles. Appropriate moisture levels are maintained by timely application of water. Temperature is generally controlled by turning the compost. The carbon-nitrogen ratio typically is controlled by altering the mix of "green" materials (such as grass clippings) and "brown" materials (such as leaves) within the material being composted. Particle size is affected by the kind of equipment used to turn windrows, mand also may be reduced by shredding incoming product before windrow formation. Generally speaking, the cost of the various methods (and the quality of the material produced) is determined by the degree to which the five above-noted variables are monitored and controlled.

A variety of composting methods exist, ranging widely in terms of technological complexity. The two basic composting methods are windrow-based technologies and in-vessel technologies. In this report we concentrate on windrow-based technologies, on the assumption that the extremely high cost of in-vessel facilities (ranging into the millions of dollars) is beyond the means of most local governments and/or that the expected benefits do not exceed the projected costs.[1]

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[1]Neither do we consider municipal solid waste composting or composting processes incorporating wastewater sludge.

Open-Windrow Composting

In essence, open-windrow composting is a simple process. Organic waste is brought to a central open air facility and formed into windrows that are three to five feet high.[2] The windrows are turned periodically to maintain a stable temperature and rate of decomposition, and water is added as needed to maintain an appropriate moisture content. After a desired level of decomposition is reached, the composted product is ready for assembly and distribution to end-users.

Although the overall process is simple, local solid waste authorities involved in operating composting facilities face a wide array of choices regarding facility design and day-to-day operations. These choices are governed by the size of the organic waste stream, the desired quality of the composted material to be produced, and budgetary limitations. Key choices made in designing composting facilities include:

- the size of facility to build
- the type of ground cover (floor) on which the windrows will be set
- the kind(s) of runoff control(s) needed to comply with groundwater and stormwater management requirements
- the kind of machinery needed for various aspects of the composting process

Key choices made regarding day-to-day operations of composting facilities include:

- the timing of windrow formation
- the frequency with which windrows are turned
- the total amount of time in which the composting process takes place
- how the finished product is readied for final disposition

The nature of these choices and the tradeoffs involved are summarized below.

Facility Size

Determining how large a composting facility to build depends on the projected size of the organic waste stream. This in turn depends on a number of factors, including the size of the local population served, the composition of housing in the area served (*e.g.*, apartments versus single-family houses), and the dominant types of local vegetation (particularly, deciduous trees versus evergreens). These vary widely; however, a useful rule of thumb is one-half ton of organic waste generation per person per year (Bob Rubin, pers. comm.).

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[2]Windrow formation may be preceded by shredding the incoming product to reduce particle size at the outset of the composting process.

Ground Cover

Composting facilities may be paved or unpaved. Unpaved facilities with a packed earth floor are decidedly cheaper to construct. However, such facilities experience considerable problems with mud during periods of heavy rain. Gravel, asphalt, or concrete may be utilized as a ground cover for paved facilities. Gravel floors can create quality control problems because of an excessive amount of rocks in the finished product. Asphalt and (especially) concrete are more expensive types of ground cover; they involve less maintenance than the other two types, however.

Machinery

A variety of equipment is required for large-scale processing of compost. Of these, the most important is the machinery used to turn the windrows. Either a standard front-end loader or a specialized compost turner may be employed for this purpose. Compost turners generally are faster and do a better job of mixing than front-end loaders. Front-end loaders are less expensive to purchase, and may be used for additional purposes such as unloading incoming waste and loading finished product.

Other types of machinery used in composting facilities include shredding equipment (such as tub grinders), conveyance devices for moving the product around, screening equipment, and baggers (for finished product). Shredding equipment speeds up decomposition by reducing particle size at the beginning of the composting process and also contributes to the quality of the finished product by making the compost more uniform in composition. Such equipment is designed to handle relatively large volumes of material, though, and is therefore most economical for relatively large-scale operations. For the same reason, conveyance devices tend to be more cost-effective for large-scale operations. Screening equipment breaks down large, bulky clumps and removes undesirable items such as non-organic materials from the finished product, thereby improving product quality (and hence marketability). The desirability of bagging equipment depends on the markets (end-users) for the finished product. A high-quality product suitable for home gardens will be more likely to be distributed or sold in small quantities, and equipment for bagging the product may be necessary. In contrast, a lower quality product used only as a low-grade soil amendment by users such as Departments of Transportation typically might be distributed in large quantities (*i.e.*, by the truckload), and bagging equipment may be not be needed.

Timing of Composting

Generation of yard waste is highly seasonal. Typically, the largest amount of organic waste is generated in autumn with the falling of leaves. A second seasonal peak is usually observed beginning in the spring, as the amount of grass clippings in the waste stream rises. A number of schedules for producing finished compost are possible, depending on local circumstances. In some communities leaf waste collected in the autumn is stored through the winter, mixed with greener waste in the spring, and allowed to decompose through the summer to produce one batch of finished product per year. In other areas—*e.g.*, communities with relatively mild climates—the flow of organic waste is steady enough to allow two to four batches of finished product to be produced per year.

For a given community, the timing of composting activities and number of batches of finished product produced each year will depend on the steadiness of yard waste creation, the quality of finished product desired, and the level of volume reduction desired. All other things equal, the longer the period in which decomposition occurs, the greater the volume reduction and the more uniform the consistency of the final product. At the same time, maintaining a desirable carbon-nitrogen ratio will depend significantly on the composition of waste material in the windrows.[3] This, too, has implications for the timing of windrow formation. For example, windrows formed in the fall will tend to have higher carbon-nitrogen ratios and will decompose more slowly than windrows containing a more balanced mix of leaves and grass clippings.

Finally, the frequency with which windrows are turned has a significant impact on the rate of decomposition, the number of batches produced per year, and the quality of the finished product. More frequent turnings require increased labor and other inputs, however, thereby adding to operating costs. Of course, if more frequent turnings contribute sufficiently to the value of the finished product, these additional costs may be offset by additional sales revenues.

OVERVIEW OF PROTOTYPE FACILITIES ANALYZED

As the previous section indicated, a host of options are available to solid waste authorities in the design and operation of yard waste composting facilities. Because the aim of this report is to summarize the costs of composting facilities of varying sizes and degrees of technological sophistication, the analysis of composting costs to be presented in the next section is organized around a set of prototypes. All prototypes feature open-air windrows that are turned periodically—neither in-vessel systems nor windrow systems in which air is piped into piles are considered.

Three types of composting systems will be examined: (a) a simple passive pile, or "minimal-tech," system requiring minimal labor and mechanical inputs; (b) a "low-tech" system featuring a paved surface and the use of a front-end loader for turning piles; and (c) a "medium-tech" system that features a paved surface, screening and shredding equipment to insure uniform consistency of the finished product, and the use of a windrow turner for turning piles. Three different waste stream levels will be considered—25,000 tons per year, 100,000 tons per year, and 200,000 tons per year—corresponding to organic waste generation of localities of different sizes.

Table 1 summarizes the prototype facilities to be considered. The minimal-tech system is the only prototype considered in which windrows are placed on an (unpaved) packed clay surface. As noted earlier, unpaved surfaces can create problems during rainy periods because

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[3]It is also possible to use fertilizer nitrogen sources to adjust the carbon-nitrogen ratio.

Table 1. Characteristics of different types of composting facilities analyzed.

Item	Minimal System	Low-tech system	Medium-tech system
Technologies			
Ground cover	Packed clay	Asphalt, concrete	Asphalt, concrete
Turning equipment	Front-end loader	Front-end loader	Compost turner
Screening/shredding equip.	No	No	Yes
Other equipment	Water pump, thermometer scale	Water pump, thermometer scale	Front-end loader water pump, thermometer scale
Miscellaneous			
Frequency of turning	2-3 times per year	1 time per month	2 times per week
Facility capacity ('000 tons/yr)	25	25, 100, and 200	25, 100, and 200
Product quality	Poor	Low to moderate	Moderate to good
Volume reduction	30%	40%	50%, 55%[a]
Processing time (months)	36	12	6

[a]Volume reduction is 55% for medium-tech facilities that use screening and shredding equipment, and 50% otherwise.

of the difficulty of moving equipment for compost turning in muddy conditions; however, given the low frequency of turnings under the minimal system (2 to 3 times per year) this likely would not be a concern. The low-tech and medium-tech prototypes are paved facilities. Two different types of paved surfaces—asphalt and concrete—will be considered for each of these prototypes.

All prototypes considered require the services of a front-end loader. In the minimal and low-tech systems, front-end loaders are used for turning windrows as well as for other tasks such as unloading incoming waste and loading finished product. The medium-tech system uses a specialized compost turner for turning windrows; this prototype also requires a front-end loader for loading and unloading tasks. Additionally, the medium-tech system is the only prototype for which screening and shredding equipment are considered.[4]

Perhaps the most important feature differentiating the three prototype facilities is the frequency with which windrows are turned. Frequency of turning directly affects the quality

[4]We also consider medium-tech facilities without screening and shredding equipment.

of the finished product, the amount of volume reduction, and the total time required to create a stabilized product. All of these factors affect facility operating costs. Under the minimal system, piles are turned only two to three times per year. The amount of time required to produce a stabilized product is lengthy (two to three years), product quality is poor, and volume reduction of approximately 30% may be expected. Under the low-tech system, piles are turned monthly, and one batch of finished product is produced per year. Volume reduction is 40%, and product quality is better. Under the medium-tech system, piles are turned twice weekly and two batches of finished product are produced per year. The medium-tech system creates a relatively high-quality product with the greatest level of volume reduction—50% or 55%, depending on whether screening and shredding equipment is used.

COSTS OF PROTOTYPE FACILITIES

In this section we present the cost estimates for different types of composting facilities. Three types of costs are considered: *(a)* construction costs; *(b)* annual fixed costs; and *(c)* annual operating costs. Construction costs include all costs associated with land acquisition, site preparation, and equipment purchase. Fixed costs include depreciation, interest on the undepreciated or remaining value of the facilities, repairs and maintenance of fixed assets, and insurance. Operating costs include the costs of labor, materials, and equipment operation.

At the outset, it is important to recognize that we are confining our analysis to activities occurring within the composting facility. Neither collection nor marketing activities will be considered here. Collection costs can be significant—indeed, these may amount to over 50% of the total cost of handling municipal yard waste (Kelly). Collection costs will vary widely, depending on population density, collection methods, and frequency of collection. Insofar as most communities already engage in collection of leaves and other yard waste, the costs presented below represent an addition to these existing costs.

The current analysis also does not consider the ultimate disposition of the finished product. How and where compost is disposed of depends fundamentally on the quality of the product and local demands for compost of different qualities. As with collection costs, markets for compost are highly variable. This variability does not lend itself to making general statements about the revenues likely to be generated from the sale of finished product.[5]

Construction Costs

Table 2 presents capital requirements for the different composting systems considered, and Table 3 presents per-unit costs of each of the capital items. Land costs of $1240 per acre are based on the 1992 average value of agricultural land without buildings (NCDA).[6] Acreage

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[5]Typically compost is given free of charge to agricultural users and sold to other users such as landscapers and nurseries.

[6]Note that in some areas, particularly those located near large or rapidly growing municipalities, land prices will be considerably higher.

Table 2. Capital requirements for different types of composting facilities.[a]

Technology	Capacity (t/year)	Land (acres)	Front-end loaders (no.)	Thermometers (no.)	Compost turners (no.)	Screener & shredder (no.)
Minimal	25,000	15	1	15	0	0
Low	25,000	5	1	5	0	0
Low	100,000	20	1	20	0	0
Medium	100,000	10	1	10	1	0
Medium-S	100,000	10	1	10	1	1
Low	200,000	40	2	40	0	0
Medium	200,000	20	1	20	1	0
Medium-S	200,000	20	1	20	1	1

[a]In addition to the items listed above, all facilities require one water pump, one above-ground scale, and one sediment basin for runoff control.

requirements vary with the type of technology employed. The minimal-technology system requires one acre for each 1,667 tons of incoming material, whereas the low- and medium-technology systems require one acre for each 5,000 and 10,000 tons of incoming material, respectively. The differing degrees of land use across systems have important implications for overall construction costs in that the most important cost components (especially surfacing) vary directly with the area of the facility.

Surfacing costs, particularly for the (paved) low- and medium-technology systems are far and away the largest component of overall start-up costs. Three paving options are considered, ranging in cost from about $63,000 per acre to $145,000 per acre.[7] The least expensive of these is to lay down 2 inches of asphalt on the area where windrows are formed (three-quarters of the area of the entire facility), and 4 inches over the staging area where considerably greater vehicular traffic occurs. The second somewhat more expensive option is to lay down 4 inches of asphalt over the entire facility. The third paving option considered is to lay down 6 inches of concrete. Concrete is considerably more durable but also about twice as expensive as asphalt.

[7]All paved surfaces are assumed to be laid down over an 8-inch bed of gravel.

Table 3. Per-unit capital costs for composting facilities.

Item	Cost per unit ($)	Assumed life (yrs)
LAND		
Land[a]	1,240	
Sediment basin[a]	540	20
Fencing[b]	6.75	20
SURFACING[a]		
Grading and compaction	5,050	20
2" Asphalt	62,920	10
4" Asphalt	72,600	10
6" Concrete	145,200	15
EQUIPMENT AND MACHINERY[c]		
Water pump	450	10
Thermometer	200	10
Scale	15,000	20
Front-end loader	112,000	10
Compost turner	129,000	10
Screening system	67,150	10
Shredding system	90,950	10

[a]Dollars per acre.
[b]Dollars per linear foot.
[c]Dollars per unit.

The equipment needed for the various prototypes was described earlier. Of note is the fact that the 200,000 ton-per-year low-technology prototype requires two front-end loaders, while all the other prototypes require only one. The additional equipment required for the medium-technology systems (a compost turner and—in the case of the "medium-S" systems—shredders and screeners), adds significantly to the overall start-up costs. The other capital items (sediment basins, water pumps, and thermometers) are relatively inexpensive by comparison.

Table 4 presents total start-up costs for the various prototypes. Start-up costs for the (unpaved) minimal-tech system are 28-57% less than paved facilities of comparable capacity, primarily because of the expense of paving. For paved facilities, the low-tech system is more expensive to construct than the medium-tech system without screening and shredding equipment for all three waste stream sizes considered, and is more expensive than the medium-S

Table 4. Start-up costs of prototype composting facilities.

		Facility surface[a]			
Tech-nology	Capacity (t/year)	Packed clay	2" & 4" Asphalt[b]	4" Asphalt	6" Concrete
Minimal	25,000	$254,185	$ --	$ --	$ --
Low	25,000	--	501,555	537,855	900,855
Medium	25,000	--	446,183	464,333	645,833
Medium-S[c]	25,000	--	604,283	622,433	803,933
Low	100,000	--	1,599,360	1,744,560	3,196,560
Medium	100,000	--	997,565	1,070,165	1,796,165
Medium-S[c]	100,000	--	1,155,665	1,228,265	1,954,265
Low	200,000	--	3,169,080	3,459,480	6,363,480
Medium	200,000	--	1,728,360	1,873,560	3,325,560
Medium-S[c]	200,000	--	1,886,460	2,031,660	3,483,660

[a]All paved surfaces include an 8" bed of gravel.
[b]2" of asphalt over staging area, 4" over the rest of the facility.
[c]Medium-S denotes a medium-technology facility that includes screening and shredding equipment.

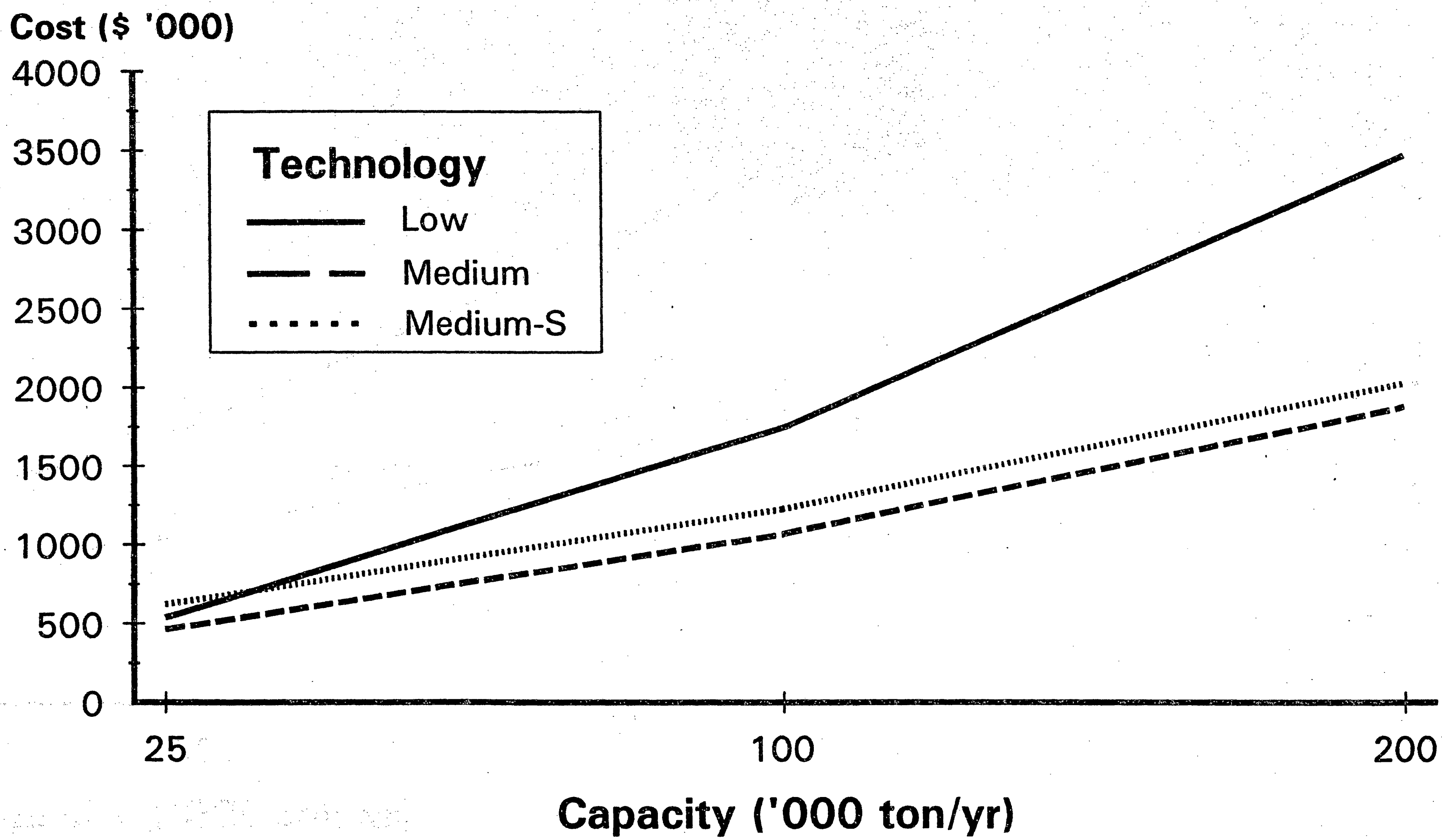
system for the two larger waste streams. The reason for this is that a low-tech facility requires twice as much area as the medium-tech systems. The medium-S facilities are in all cases more costly to construct than the medium facilities because of the additional expenditures on screening and shredding equipment.

The start-up costs of paved facilities increase with the quality of the paving surface (*i.e.*, as one moves from left to right across each row of Table 4). Comparison of the start-up costs of the medium and medium-S systems indicates that cost differences narrow as facility size increases (Figure 1). Figure 1 also indicates that the startup costs rise considerably faster for low-tech facilities than for medium-tech facilities as the amount of waste handled increases.

Fixed Costs

Fixed costs for the various types of facilities were computed based on their start-up costs. These include interest on debt incurred in construction and equipment purchase, insurance, property taxes, and depreciation. These were computed assuming an 8% simple interest rate;

Figure 1. Start-up costs for different types of composting facilities*



* For facilities with 4" asphalt surface

annual insurance costs of 1% of the value of fixed assets (excluding land); repair and maintenance costs of 1% of the value of fixed assets; and straightline depreciation over the lifetime of the assets.

Table 5 shows the fixed costs for the various types and sizes of facilities. A more detailed breakdown of fixed costs is found in the Appendix. For paved facilities, these range between $85,000 and $145,000 for 25,000 tons of annual capacity (compared with $43,000 for the minimal-tech system); between $187,000 and $502,000 for 100,000 tons of annual capacity; and $322,000 and $1,001,000 for 200,000 tons of annual capacity. The relative costs among different types of systems and over different paving surfaces is similar to the relationships observed for start-up costs.

Operating Costs

Annual operating costs for the various types of facilities are given in Table 6. These include labor costs for daily operation, maintenance and operating costs for the relevant equipment, and charges for water use. For the most part, these vary directly with the quantity of incoming waste handled. An exception is that all facilities were assumed to be open to receive incoming material 10 hours per week, and hence required 520 hours of labor each year for that purpose. A detailed breakdown of operating costs is found in the Appendix.

Depending on the size of the facility, annual operating costs of low-tech facilities are between 31% and 45% greater than those of medium-tech facilities.[8] This is largely attributable to the greater use of labor and equipment (*i.e.*, front-end loaders) for turning operations in the low-tech system. The per-hour cost of operating a compost turner used in the medium-tech systems is roughly 60% greater than the per-hour cost of operating a front-end loader; however, turning windrows with a front-end loader requires more than twice as much time. This results in greater expenditure on both equipment and the labor necessary to operate that equipment in the low-tech system.[9]

Total Costs

Table 7 presents the total annual costs of the various prototype composting facilities. These are the sums of annual fixed and operating costs (from Tables 5 and 6). For paved facilities, total costs range from $118,000 to $190,000 for 25,000 ton-per-year facilities; $291,000 to $651,000 for the 100,000 ton-per-year facilities; and $520,000 to $1,288,000 for the 200,000 ton-per-year facilities. By way of comparison, total annual costs for the 25,000 ton-per-year minimal-tech facility are approximately $66,000. Generally, the medium-tech systems maintain a clear cost advantage over the low-tech system at all levels of throughput. Comparison of total costs across prototypes for waste levels of 25,000 tons per year indicates

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[8]Operating costs for the minimal-tech system are 30-47% less than those for paved systems of comparable capacity.

[9]For example, a 100,000 ton-per-year low-tech facility requires 2880 hours annually for turning operations. In contrast, a similarly sized medium-tech facility requires only 1296 hours per year for the same purpose. Average hourly operating costs of front-end loaders and compost turners are $16 and $26, respectively.

Table 5. Annual fixed costs of prototype composting facilities.[a]

Tech-nology	Capacity (t/year)	Facility surface[b] Packed Clay	2" & 4" Asphalt[c]	4" Asphalt	6" Concrete
Minimal	25,000	$42,598	$ --	$ --	$ --
Low	25,000	--	96,540	100,437	145,207
Medium	25,000	--	85,347	88,795	111,180
Medium-S	25,000	--	114,717	118,165	140,550
Low	100,000	--	296,263	323,851	502,931
Medium	100,000	--	187,075	200,869	290,409
Medium-S[d]	100,000	--	218,695	232,489	322,029
Low	200,000	--	588,057	643,233	1,001,393
Medium	200,000	--	322,063	349,651	528,731
Medium-S[d]	200,000	--	353,683	381,271	560,351

[a]Fixed costs include interest (at an assumed 8% simple intererest rate); insurance (at an assumed rate of 1% of the value of fixed assets per year), and repairs and maintenance (at an assumed rate of 1% of the value of fixed assets per year); and straightline depreciation over the lifetime of the asset. All machinery is assumed to have a lifetime of ten years, while land amendments (paving and grading) and sediment basins are assumed to have lifetimes of twenty years

bAll paved surfaces include an 8" bed of gravel.

[c]2" of asphalt over staging area, 4" over the rest of the facility.

[d]Medium-S denotes a medium-technology facility that includes screening and shredding equipment.

that the low-tech system is less expensive to operate than the medium-S system (for facilities paved with asphalt) but more expensive than the medium system. At higher levels of waste, a low-tech facility is more expensive to operate than either of the medium-tech facilities in all cases, an indication of economies of scale for the more sophisticated systems.

Table 8 and Figure 2 present unit costs of the various prototypes from the perspective of both cost per ton of incoming waste and cost per ton of finished product. Cost per input ton is useful for purposes of comparing composting with alternative means of waste disposal (*i.e.*, landfilling); cost per output ton (in combination with information on collection and marketing costs and revenues from sales of composted material) is the appropriate measure for gauging the profitability of composting.

Table 6. Annual operating costs of prototype composting facilities.

Technology	Capacity (t/year)	Water	Equipment	Labor	Total
Minimal	25,000	$ 2,250	$ 4,331	$ 16,975	$ 23,556
Low	25,000	2,250	13,831	28,850	44,931
Medium	25,000	2,250	10,791	20,805	33,846
Medium-S[a]	25,000	2,250	10,890	20,942	34,083
Low	100,000	9,000	55,325	84,200	148,525
Medium	100,000	9,000	43,163	52,020	104,183
Medium-S[a]	100,000	9,000	43,561	52,570	105,131
Low	200,000	18,000	110,650	158,000	286,650
Medium	200,000	18,000	86,326	93,640	197,966
Medium-S[a]	200,000	18,000	87,123	94,740	199,863

[a]Medium-S denotes a medium-technology facility that includes screening and shredding equipment.

For paved facilities, costs per input ton range between $2.60 and $7.61. By way of comparison, average operating costs per inpput ton of operating a Sub-title D lined landfill range from $8.00 to $19.50 (EPA, 1989)—in other words, composting appears to be a much cheaper alternative for the disposal of organic waste. Costs per output ton range from $5.20 to $15.53.[10]

SUMMARY AND CONCLUSIONS

In this report we have presented detailed cost estimates for the construction and operation of a variety of prototypical yard waste composting facilities. The level of technical sophistication of the facilities considered ranged from a primitive "minimal-tech" system to a moderately sophisticated "medium-tech" system employing specialized composting equipment. We also considered facilities of different processing capacities to shed light on the cost of yard waste composting for communities of different sizes (*i.e.*, different levels of yard waste generation).

By far the dominant component of start-up costs in establishing a yard waste composting facility is surfacing. For this reason, paved facilities were found to be significantly more

[10]Costs per output ton for the minimal-tech facility considered are $3.78. However, end uses for the product are extremely limited given the poor quality of this material.

Table 7. Total annual costs of prototype composting facilities.[a]

		Facility surface[b]			
Technology	Capacity (t/year)	Packed Clay	2" & 4" Asphalt[c]	4" Asphalt	6" Concrete
Minimal	25,000	$66,154	$ --	$ --	$ --
Low	25,000	--	138,471	145,368	190,138
Medium	25,000	--	118,793	122,641	145,026
Medium-S[d]	25,000	--	148,880	152,248	174,633
Low	100,000	--	444,788	472,376	651,456
Medium	100,000	--	291,258	305,052	394,592
Medium-S[d]	100,000	--	323,826	337,620	427,160
Low	200,000	--	874,707	929,883	1,288,043
Medium	200,000	--	520,029	547,617	726,697
Medium-S[d]	200,000	--	553,546	581,134	760,214

[a]These are the sums of annual operating costs and fixed costs.
[b]All paved surfaces include an 8" bed of gravel.
[c]2" of asphalt over staging area, 4" over the rest of the facility.
[d]Medium-S denotes a medium-technology facility that includes screening and shredding equipment.

expensive to construct than the (unpaved) minimal-tech facility. Depending on capacity, start-up costs of paved facilities ranged from about $450,000 into the millions of dollars; start-up costs for an unpaved facility were 43 to 72% less. Clearly, the abilities of local governments to raise these amounts of money will be important determinants of the kinds of facilities that can be feasibly constructed. Interestingly, low-tech facilities were in most cases found to be more expensive to build than medium-tech facilities because of the greater area required.

Total annual costs of the compost facilities analyzed—including both fixed and operating costs—were found to range from about $66,000 to over $1,250,000, depending on the type of system and the capacity of the facility. Annual costs for a minimal-tech system were considerably less than those of the other facilities considered. Low-tech facilities were in all cases found to be more expensive to operate than medium-tech facilities. On a per-input-ton basis, composting costs ranged from $2.60 to $7.61 per ton handled. These figures compare favorably with average operating costs of a lined sanitary landfill, indicating that composting

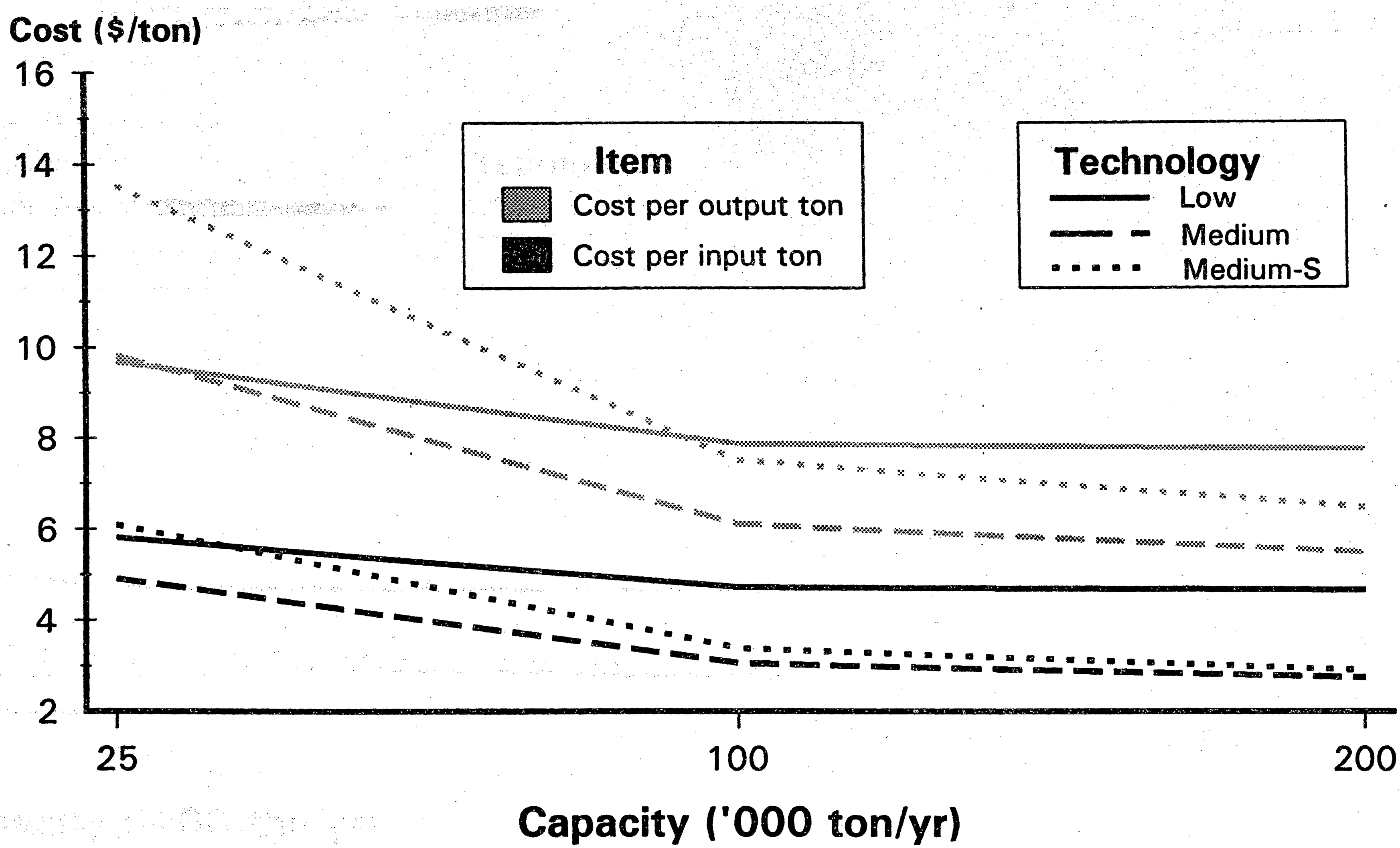
Table 8. Per-ton cost of prototype composting facilities.

Tech-nology	Capacity (t/year)	Facility surface: Packed Clay	2" & 4" Asphalt	4" Asphalt	6" Concrete
		Cost per input ton ($)			
Minimal	25,000	2.65	--	--	--
Low	25,000	--	5.54	5.81	7.61
Medium	25,000	--	4.75	4.91	5.80
Medium-S[a]	25,000	--	5.96	6.09	6.99
Low	100,000	--	4.45	4.72	6.51
Medium	100,000	--	2.91	3.05	3.95
Medium-S[a]	100,000	--	3.24	3.38	4.27
Low	200,000	--	4.37	4.65	6.44
Medium	200,000	--	2.60	2.74	3.63
Medium-S[a]	200,000	--	2.77	2.91	3.80
		Cost per output ton ($)[b]			
Minimal	25,000	3.78	--	--	--
Low	25,000	--	9.23	9.68	12.68
Medium	25,000	--	9.50	9.82	11.60
Medium-S[a]	25,000	--	13.24	13.53	15.53
Low	100,000	--	7.42	7.87	10.85
Medium	100,000	--	5.82	6.10	7.90
Medium-S[a]	100,000	--	7.20	7.51	9.49
Low	200,000	--	7.28	7.75	10.73
Medium	200,000	--	5.20	5.48	7.26
Medium-S[a]	200,000	--	6.16	6.47	8.44

[a]Medium-S denotes a medium technology facility that includes screening and shredding equipment.

[b]Assumes volume reductions of 30%, 40%, 50%, and 55% for Minimal, Low, Medium, and Medium-S technologies, respectively.

Figure 2. Cost per ton for different types of composting facilities*



* For facilities with 4" asphalt surface

represents a cost-effective way of processing the fraction of the waste stream made up by yard waste.

Two conclusions may be drawn from the results of the analyses presented here. First, in deciding on the type of compost facility to build, communities should confine their choices to either a minimal-tech system or a medium-tech system. The unpaved minimal-tech system is considerably cheaper to build and operate; however, the low quality of the material produced in all likelihood will significantly limit the amount of that product that can be marketed (or even given away). Indeed, one can easily imagine a situation in which minimal-tech facilities become *de facto* "organic landfills" if demand for the product of such facilities is low or absent.

Second, among the paved facilities considered, the medium-tech systems clearly dominate the low-tech systems in terms of cost-effectiveness. As the primary difference between these two types of facilities is the use of a specialized compost turner for the medium-tech systems, this amounts to a strong endorsement of the use of that piece of equipment in yard waste composting. The issue of whether the use of additional equipment (*i.e.*, screens and shredders) is desirable at medium-tech facilities will depend largely on the markets for compost and the scale of operations. As this additional equipment enhances product quality, purchase and use of this equipment may be justified if sufficient demand exists for a higher-quality, higher-revenue product. Additionally, there appear to be economies of scale in the use of this equipment in that the cost differences between the medium and medium-S systems narrowed as the volume of material handled increased.

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APPENDIX

APPENDIX

Data for cost estimates presented in the text and for the more detailed breakdown of costs presented in the following tables came from a variety of sources. These are described below.

Facility Size Estimates

These data were compiled from several sources. Pile sizes for facilities of different sizes were drawn from the *BioCycle Guide to Yardwaste Composting*, as well as from personal communication with individuals associated with specific composting facilities throughout North Carolina. Using these pile size data and the operating specifications for front-end loaders and compost turners, an estimate of the total area needed (including spaces for equipment turnaround) was computed. The total facility size was then compiled using estimates of tons per cubic yard and cubic yards per linear foot of pile presented in the *Virginia Yardwaste Management Manual*. It was assumed that staging and receiving areas required one-quarter of total facility area.

Start-up Cost Estimates

Land cost figures were based on average farmland prices published in *North Carolina Agricultural Statistics*. Costs of constructing a sediment basin grading of the land were based on rough estimates provided by a local construction company. These assumed land that was already cleared and ready for grading. Estimates for the actual paving of the area both asphalt and concrete were provided by a local paving firm. Equipment purchase prices were those quoted by local retail outlets.

Operating Cost Estimates

The times of operations were provided by the spec sheets from the individual equipment manufacturers and when needed a follow-up phone call was used to get more specific information (including processing limitations and hourly capabilities for screening systems and front-end loaders). Normal maintenance costs were included in operating costs for all machinery. All estimates were based on for "semi-rough" conditions. Time and cost estimates for processing the compost piles were drawn from spec sheets for compost turners and performance handbooks for front-end loaders. Estimates of water requirements were taken from the *Virginia Yardwaste Management Manual.* Data on rainfall were obtained from the Wake County Cooperative Extension Service office.

APPENDIX TABLES

Table A-1a. Capital costs for 25,000-ton minimal-tech system

Item	Description	Unit	Life	Qty	Cost per unit	Total cost
Land	Original farmland	acre	-	15	1240	18600
Improvements	Grading 1.5%	acre	20	15	5050	75750
Fencing	8′ chain-linked, commercial	foot	20	3300	6.45	21285
Sediment Basin	Trench with drainpipe	acre	20	15	540	8100
Subtotal						123735
Paving						
4" asphalt over staging	2" asphalt over 8" gravel	acre	10	11.25	62920	707850
2" over the remainder	4" asphalt over 8" gravel	acre	10	3.75	72600	272250
4" over total area	4" asphalt over 8" gravel	acre	10	15	72600	1089000
	6" concrete	acre	15	15	145200	2178000
Machinery and Equipment						
Water pump	water pump	each	10	1	450	450
Front-end loader	With 3 yd bucket	each	10	1	112000	112000
Thermometer	6′ industrial	each	10	15	200	3000
Scale	Above-ground, installed	each	20	1	15000	15000
Subtotal						130450

Table A-1b. Annual fixed costs for 25,000-ton minimal-tech system

Item	Description	Depreciation	Interest (simple 8%)	Insurance (1% rate)	Repairs (1% rate)	Total cost
Land	Original farmland	-	1488	-	-	1488
Improvements	Grading 1.5%	3788	6060	758	758	11363
Fencing	8′ chain-linked, commercial	1064	1703	213	213	3193
Sediment basin	Trench with drainpipe	405	648	81	81	1215
Subtotal						17258
Paving	2" & 4" asphalt	98010	78408	-	9801	
	4" asphalt	108900	87120	-	10890	206910
	6" concrete	145200	174240	-	21780	341220
Machinery and Equipment						
Water pump	Water pump	45	36	4.5	4.5	90
Front-end loader	With 3 yd bucket	11200	8960	1120	1120	22400
Thermometer	6′ industrial	300	240	30	30	600
Scale	Above-ground, installed	750	1200	150	150	2250
Subtotal						25340

Table A-1c. Annual labor and machinery operating costs for 25,000-ton minimal-tech system

Annual Labor and Machinery Operations

Operation	Item	Labor (hrs)	Machinery (hrs)
Receiving	Scales	520	-
Staging	Front-end loader	40	40
Creating windrows	Front-end loader	62.5	62.5
	Water pump	62.5	62.5
Turning windrows	Front-end loader	120	120
Removal of final product	Front-end loader	43.75	43.75
Total		848.75	328.75

Annual Variable Costs

Item	Unit	Cost per unit	Qty	Total cost
Water	gal	0.0045	500000	2250
Water pump	hr	1.14	62.5	71
Front-end loader	hr	16	266.25	4260
Labor	hr	20	848.75	16975
Total				23556

Table A-2a. Capital costs for 25,000-ton low-tech facility

Item	Description	Unit	Life	Qty	Cost per unit	Total cost
Land	Original farmland	acre	-	5	1240	6200
Improvements	Grading 1.5%	acre	20	5	5050	25250
Fencing	8′ chain-linked, commercial	foot	20	1900	6.45	12255
Sediment Basin	Trench with drainpipe	acre	20	5	540	2700
Subtotal						46405
Paving						
4" asphalt over staging	2" asphalt over 8" gravel	acre	10	3.75	62920	235950
2" over the remainder	4" asphalt over 8" gravel	acre	10	1.25	72600	90750
4" over total area	4" asphalt over 8" gravel	acre	10	5	72600	363000
	6" concrete	acre	15	5	145200	726000
Machinery and Equipment						
Water pump	water pump	each	10	1	450	450
Front-end loader	With 3 yd bucket	each	10	1	112000	112000
Thermometer	6′ industrial	each	10	5	200	1000
Scale	Above-ground, installed	each	20	1	15000	15000
Subtotal						128450

Table A-2b. Annual fixed costs for 25,000-ton low-tech facility

Item	Description	Depreciation	Interest (simple 8%)	Insurance (1% rate)	Repairs (1% rate)	Total cost
Land	Original farmland	-	496	-	-	496
Improvements	Grading 1.5%	1263	2020	253	253	3788
Fencing	8′ chain-linked, commercial	613	980	123	123	1838
Sediment basin	Trench with drainpipe	135	216	27	27	405
Subtotal						6527
Paving	2" & 4" asphalt	32670	26136	-	3267	62073
	4" asphalt	36300	29040	-	3630	68970
	6" concrete	48400	58080	-	7260	113740
Machinery and Equipment						
Water pump	Water pump	45	36	4.5	4.5	90
Front-end loader	With 3 yd bucket	11200	8960	1120	1120	22400
Thermometer	6′ industrial	100	80	10	10	200
Scale	Above-ground, installed	750	1200	150	150	2250
Subtotal						24940

Table A-2c. Annual labor and machinery operating costs for 25,000-ton low-tech facility

Annual Labor and Machinery Operations

Operation	Item	Labor (hrs)	Machinery (hrs)
Receiving	Scales	520	-
Staging	Front-end loader	40	40
Creating windrows	Front-end loader	62.5	62.5
	Water pump	62.5	62.5
Turning windrows	Front-end loader	720	720
Removal of final product	Front-end loader	37.5	37.5
Total		1442.5	922.5

Annual Variable Costs

Item	Unit	Cost per unit	Qty	Total cost
Water	gal	0.0045	500000	2250
Water pump	hr	1.14	62.5	71
Front-end loader	hr	16	860	13760
Labor	hr	20	1442.5	28850
Total				44931

Table A-3a. Capital costs for 25,000-ton medium-tech facility

Item	Description	Unit	Life	Qty	Cost per unit	Total cost
Land	Original farmland	acre	-	2.5	1240	3100
Improvements	Grading 1.5%	acre	20	2.5	5050	12625
Fencing	8′ chain-linked, commercial	foot	20	1350	6.45	8708
Sediment Basin	Trench with drainpipe	acre	20	2.5	540	1350
Subtotal						25783
Paving						
4" asphalt over staging	2" asphalt over 8" gravel	acre	10	1.875	62920	117975
2" over the remainder	4" asphalt over 8" gravel	acre	10	0.625	72600	45375
4" over total area	4" asphalt over 8" gravel	acre	10	2.5	72600	181500
	6" concrete	acre	15	2.5	145200	363000
Machinery and Equipment						
Water pump	water pump	each	10	1	450	450
Front-end loader	With 3 yd bucket	each	10	1	112000	112000
Compost turner		each	10	1	129000	129000
Thermometer	6′ industrial	each	10	3	200	600
Scale	Above-ground, installed	each	20	1	15000	15000
Subtotal						257050

Table A-3b. Annual fixed costs for 25,000-ton medium-tech facility

Item	Description	Depreciation	Interest (simple 8%)	Insurance (1% rate)	Repairs (1% rate)	Total cost
Land	Original farmland	-	248	-	-	248
Improvements	Grading 1.5%	631	1010	126	126	1894
Fencing	8′ chain-linked, commercial	435	697	87	87	1306
Sediment basin	Trench with drainpipe	68	108	14	14	203
Subtotal						3650
Paving	2" & 4" asphalt	16335	13068	-	1634	31037
	4" asphalt	18150	14520	-	1815	34485
	6" concrete	24200	29040	-	3630	56870
Machinery and Equipment						
Water pump	Water pump	45	36	4.5	4.5	90
Front-end loader	With 3 yd bucket	11200	8960	1120	1120	22400
Compost turner		12900	10320	1290	1290	25800
Thermometer	6′ industrial	60	48	6	6	120
Scale	Above-ground, installed	750	1200	150	150	2250
Subtotal						50660

Table A-3c. Annual labor and machinery operating costs for 25,000-ton medium-tech facility

Annual Labor and Machinery Operations

Operation	Item	Labor (hrs)	Machinery (hrs)
Receiving	Scales	520	-
Staging	Front-end loader	40	40
Creating windrows	Front-end loader	62.5	62.5
	Water pump	62.5	62.5
Turning windrows	Compost turner	324	324
Removal of final product	Front-end loader	31.25	31.25
Total		1040.25	520.25

Annual Variable Costs

Item	Unit	Cost per unit	Qty	Total cost
Water	gal	0.0045	500000	2250
Water pump	hr	1.14	62.5	71
Front-end loader	hr	16	133.75	2140
Compost turner	hr	26	324	8580
Labor	hr	20	1040.25	20805
Total				33846

Table A-4a. Capital costs for 25,000-ton medium-S facility

Item	Description	Unit	Life	Qty	Cost per unit	Total cost
Land	Original farmland	acre	-	2.5	1240	3100
Improvements	Grading 1.5%	acre	20	2.5	5050	12625
Fencing	8′ chain-linked, commercial	foot	20	1350	6.45	8708
Sediment Basin	Trench with drainpipe	acre	20	2.5	540	1350
Subtotal						25783
Paving						
4" asphalt over staging	2" asphalt over 8" gravel	acre	10	1.875	62920	117975
2" over the remainder	4" asphalt over 8" gravel	acre	10	0.625	72600	45375
4" over total area	4" asphalt over 8" gravel	acre	10	2.5	72600	181500
	6" concrete	acre	15	2.5	145200	363000
Machinery and Equipment						
Water pump	water pump	each	10	1	450	450
Front-end loader	With 3 yd bucket	each	10	1	112000	112000
Compost turner		each	10	1	129000	129000
Screening system		each	10	1	67150	67150
Shredding system		each	10	1	90950	90950
Thermometer	6′ industrial	each	10	3	200	600
Scale	Above-ground, installed	each	20	1	15000	15000
Subtotal						415150

Table A-4b. Annual fixed costs for 25,000-ton medium-S facility

Item	Description	Depreciation	Interest (simple 8%)	Insurance (1% rate)	Repairs (1% rate)	Total cost
Land	Original farmland	-	248	-	-	248
Improvements	Grading 1.5%	631	1010	126	126	1894
Fencing	8′ chain-linked, commercial	435	697	87	87	1306
Sediment basin	Trench with drainpipe	68	108	14	14	203
Subtotal						3650
Paving	2" & 4" asphalt	16335	13068	-	1634	31037
	4" asphalt	18150	14520	-	1815	34485
	6" concrete	24200	29040	-	3630	56870
Machinery and Equipment						
Water pump	Water pump	45	36	4.5	4.5	90
Front-end loader	With 3 yd bucket	11200	8960	1120	1120	22400
Compost turner		12900	10320	1290	1290	25800
Screening system		6715	5372	672	672	13430
Shredding system		9095	7276	910	910	18190
Thermometer	6′ industrial	60	48	6	6	120
Scale	Above-ground, installed	750	1200	150	150	2250
Subtotal						80030

Table A-4c. Annual labor and machinery operating costs for 25,000-ton medium-S facility

Annual Labor and Machinery Operations

Operation	Item	Labor (hrs)	Machinery (hrs)
Receiving	Scales	520	-
Shredding	Shredder	5	5
	Front-end loader	5	5
Staging	Front-end loader	40	40
Creating windrows	Front-end loader	62.5	62.5
	Water pump	62.5	62.5
Turning windrows	Compost turner	324	324
Screening	Screening system		2
Removal of final product	Front-end loader	28.1	28.1
Total		1047.1	529.1

Annual Variable Costs

Item	Unit	Cost per unit	Qty	Total cost
Water	gal	0.0045	500000	2250
Water pump	hr	1.14	62.5	71
Front-end loader	hr	16	135.6	2170
Compost turner	hr	26	324	8580
Screening system	hr	6	2	12
Shredding system	hr	12	5	58
Labor	hr	20	1047	20943
Total				34083

Table A-5a. Capital costs for 100,000-ton low-tech facility

Item	Description	Unit	Life	Qty	Cost per unit	Total cost
Land	Original farmland	acre	-	20	1240	24800
Improvements	Grading 1.5%	acre	20	20	5050	101000
Fencing	8′ chain-linked, commercial	foot	20	3800	6.45	24510
Sediment Basin	Trench with drainpipe	acre	20	20	540	10800
Subtotal						161110
Paving						
4" asphalt over staging	2" asphalt over 8" gravel	acre	10	15	62920	943800
2" over the remainder	4" asphalt over 8" gravel	acre	10	5	72600	363000
4" over total area	4" asphalt over 8" gravel	acre	10	20	72600	1452000
	6" concrete	acre	15	20	145200	2904000
Machinery and Equipment						
Water pump	water pump	each	10	1	450	450
Front-end loader	With 3 yd bucket	each	10	1	112000	112000
Thermometer	6′ industrial	each	10	20	200	4000
Scale	Above-ground, installed	each	20	1	15000	15000
Subtotal						131450

Table A-5b. Annual fixed costs for 100,000-ton low-tech facility

Item	Description	Depreciation	Interest (simple 8%)	Insurance (1% rate)	Repairs (1% rate)	Total cost
Land	Original farmland	-	1984	-	-	1984
Improvements	Grading 1.5%	5050	8080	1010	1010	15150
Fencing	8′ chain-linked, commercial	1226	1961	245	245	3677
Sediment basin	Trench with drainpipe	540	864	108	108	1620
Subtotal						22431
Paving	2" & 4" asphalt	130680	104544	-	13068	248292
	4" asphalt	145200	116160	-	14520	275880
	6" concrete	193600	232320	-	29040	454960
Machinery and Equipment						
Water pump	Water pump	45	36	4.5	4.5	90
Front-end loader	With 3 yd bucket	11200	8960	1120	1120	22400
Thermometer	6′ industrial	400	320	40	40	800
Scale	Above-ground, installed	750	1200	150	150	2250
Subtotal						25540

Table A-5c. Annual labor and machinery operating costs for 100,000-ton low-tech facility

Annual Labor and Machinery Operations

Operation	Item	Labor (hrs)	Machinery (hrs)
Receiving	Scales	520	-
Staging	Front-end loader	160	160
Creating windrows	Front-end loader	250	250
	Water pump	250	250
Turning windrows	Compost turner	2880	2880
Removal of final product	Front-end loader	150	150
Total		4210	3690

Annual Variable Costs

Item	Unit	Cost per unit	Qty	Total cost
Water	gal	0.0045	2000000	9000
Water pump	hr	1.14	250	285
Front-end loader	hr	16	3440	55040
Labor	hr	20	4210	84200
Total				148525

Table A-6a. Capital costs for 100,000-ton medium-tech facility

Item	Description	Unit	Life	Qty	Cost per unit	Total cost
Land	Original farmland	acre	-	10	1240	12400
Improvements	Grading 1.5%	acre	20	10	5050	50500
Fencing	8′ chain-linked, commercial	foot	20	2700	6.45	17415
Sediment Basin	Trench with drainpipe	acre	20	10	540	5400
Subtotal						85715
Paving						
4" asphalt over staging	2" asphalt over 8" gravel	acre	10	7.5	62920	471900
2" over the remainder	4" asphalt over 8" gravel	acre	10	2.5	72600	181500
4" over total area	4" asphalt over 8" gravel	acre	10	10	72600	726000
	6" concrete	acre	15	10	145200	1452000
Machinery and Equipment						
Water pump	water pump	each	10	1	450	450
Front-end loader	With 3 yd bucket	each	10	1	112000	112000
Compost turner		each	10	1	129000	129000
Thermometer	6′ industrial	each	10	10	200	2000
Scale	Above-ground, installed	each	20	1	15000	15000
Subtotal						258450

Table A-6b. Annual fixed costs for 100,000-ton medium-tech facility

Item	Description	Depreciation	Interest (simple 8%)	Insurance (1% rate)	Repairs (1% rate)	Total cost
Land	Original farmland	-	992	-	-	992
Improvements	Grading 1.5%	2525	4040	505	505	7575
Fencing	8′ chain-linked, commercial	871	1393	174	174	2612
Sediment basin	Trench with drainpipe	270	432	54	54	810
Subtotal						11989
Paving	2" & 4" asphalt	65340	52272	-	6534	124146
	4" asphalt	72600	58080	-	7260	137940
	6" concrete	96800	116160	-	14520	227480
Machinery and Equipment						
Water pump	Water pump	45	36	4.5	4.5	90
Front-end loader	With 3 yd bucket	11200	8960	1120	1120	22400
Compost turner		12900	10320	1290	1290	25800
Thermometer	6′ industrial	200	160	20	20	400
Scale	Above-ground, installed	750	1200	150	150	2250
Subtotal						50940

Table A-6c. Annual labor and machinery operating costs for 100,000-ton medium-tech facility

Annual Labor and Machinery Operations

Operation	Item	Labor (hrs)	Machinery (hrs)
Receiving	Scales	520	-
Staging	Front-end loader	160	160
Creating windrows	Front-end loader	250	250
	Water pump	250	250
Turning windrows	Compost turner	1296	1296
Removal of final product	Front-end loader	125	125
Total		2601	2081

Annual Variable Costs

Item	Unit	Cost per unit	Qty	Total cost
Water	gal	0.0045	2000000	9000
Water pump	hr	1.14	250	285
Front-end loader	hr	16	535	8560
Compost turner	hr	26	1296	34318
Labor	hr	20	2601	52020
Total				104183

Table A-7a. Capital costs for 100,000-ton medium-S facility

Item	Description	Unit	Life	Qty	Cost per unit	Total cost
Land	Original farmland	acre	-	10	1240	12400
Improvements	Grading 1.5%	acre	20	10	5050	50500
Fencing	8′ chain-linked, commercial	foot	20	2700	6.45	17415
Sediment Basin	Trench with drainpipe	acre	20	10	540	5400
Subtotal						85715
Paving						
4" asphalt over staging	2" asphalt over 8" gravel	acre	10	7.5	62920	471900
2" over the remainder	4" asphalt over 8" gravel	acre	10	2.5	72600	181500
4" over total area	4" asphalt over 8" gravel	acre	10	10	72600	726000
	6" concrete	acre	15	10	145200	1452000
Machinery and Equipment						
Water pump	water pump	each	10	1	450	450
Front-end loader	With 3 yd bucket	each	10	1	112000	112000
Compost turner		each	10	1	129000	129000
Screening system		each	10	1	67150	67150
Shredding system		each	10	1	90950	90950
Thermometer	6′ industrial	each	10	10	200	2000
Scale	Above-ground, installed	each	20	1	15000	15000
Subtotal						416550

Table A-7b. Annual fixed costs for 100,000-ton medium-S facility

Item	Description	Depreciation	Interest (simple 8%)	Insurance (1% rate)	Repairs (1% rate)	Total cost
Land	Original farmland	-	992	-	-	992
Improvements	Grading 1.5%	2525	4040	505	505	7575
Fencing	8′ chain-linked, commercial	871	1393	174	174	2612
Sediment basin	Trench with drainpipe	270	432	54	54	810
Subtotal						11989
Paving	2" & 4" asphalt	65340	52272	-	6534	124146
	4" asphalt	72600	58080	-	7260	137940
	6" concrete	96800	116160	-	14520	227480
Machinery and Equipment						
Water pump	Water pump	45	36	4.5	4.5	90
Front-end loader	With 3 yd bucket	11200	8960	1120	1120	22400
Compost turner		12900	10320	1290	1290	25800
Screening system		6715	5372	672	672	13430
Shredding system		9095	7276	910	910	18190
Thermometer	6′ industrial	200	160	20	20	400
Scale	Above-ground, installed	750	1200	150	150	2250
Subtotal						82560

Table A-7c. Annual labor and machinery operating costs for 100,000-ton medium-S facility

Annual Labor and Machinery Operations

Operation	Item	Labor (hrs)	Machinery (hrs)
Receiving	Scales	520	-
Shredding	Shredder	20	20
	Front-end loader	20	20
Staging	Front-end loader	160	160
Creating windrows	Front-end loader	250	250
	Water pump	250	250
Turning windrows	Compost turner	1296	1296
Screening	Screening system		8
Removal of final product	Front-end loader	113	113
Total		2629	2117

Annual Variable Costs

Item	Unit	Cost per unit	Qty	Total cost
Water	gal	0.0045	2000000	9000
Water pump	hr	1.14	250	285
Front-end loader	hr	16	543	8680
Compost turner	hr	26	1296	34318
Screening system	hr	6	8	46
Shredding system	hr	12	20	232
Labor	hr	20	2629	52570
Total				105131

Table A-8a. Capital costs for 200,000-ton low-tech facility

Item	Description	Unit	Life	Qty	Cost per unit	Total cost
Land	Original farmland	acre	-	40	1240	49600
Improvements	Grading 1.5%	acre	20	40	5050	202000
Fencing	8′ chain-linked, commercial	foot	20	5400	6.45	34830
Sediment Basin	Trench with drainpipe	acre	20	40	540	21600
Subtotal						308030
Paving						
4" asphalt over staging	2" asphalt over 8" gravel	acre	10	30	62920	1887600
2" over the remainder	4" asphalt over 8" gravel	acre	10	10	72600	726000
4" over total area	4" asphalt over 8" gravel	acre	10	40	72600	2904000
	6" concrete	acre	15	40	145200	5808000
Machinery and Equipment						
Water pump	water pump	each	10	1	450	450
Front-end loader	With 3 yd bucket	each	10	2	112000	224000
Thermometer	6′ industrial	each	10	40	200	8000
Scale	Above-ground, installed	each	20	1	15000	15000
Subtotal						247450

Table A-8b. Annual fixed costs for 200,000-ton low-tech facility

Item	Description	Depreciation	Interest (simple 8%)	Insurance (1% rate)	Repairs (1% rate)	Total cost
Land	Original farmland	-	3968	-	-	3968
Improvements	Grading 1.5%	10100	16160	2020	2020	30300
Fencing	8′ chain-linked, commercial	1742	2786	348	348	5225
Sediment basin	Trench with drainpipe	1080	1728	216	216	3240
Subtotal						42733
Paving	2" & 4" asphalt	261360	209088	-	26136	496584
	4" asphalt	290400	232320	-	29040	551760
	6" concrete	387200	464640	-	58080	909920
Machinery and Equipment						
Water pump	Water pump	45	36	4.5	4.5	90
Front-end loader	With 3 yd bucket	22400	17920	2240	2240	44800
Thermometer	6′ industrial	800	640	80	80	1600
Scale	Above-ground, installed	750	1200	150	150	2250
Subtotal						48740

Table A-8c. Annual labor and machinery operating costs for 200,000-ton low-tech facility

Annual Labor and Machinery Operations

Operation	Item	Labor (hrs)	Machinery (hrs)
Receiving	Scales	520	-
Staging	Front-end loader	320	320
Creating windrows	Front-end loader	500	500
	Water pump	500	500
Turning windrows	Compost turner	5760	5760
Removal of final product	Front-end loader	300	300
Total		7900	7380

Annual Variable Costs

Item	Unit	Cost per unit	Qty	Total cost
Water	gal	0.0045	4000000	18000
Water pump	hr	1.14	500	570
Front-end loader	hr	16	6880	110080
Labor	hr	20	7900	158000
Total				286650

Table A-9a. Capital costs for 200,000-ton medium-tech facility

Item	Description	Unit	Life	Qty	Cost per unit	Total cost
Land	Original farmland	acre	-	20	1240	24800
Improvements	Grading 1.5%	acre	20	20	5050	101000
Fencing	8′ chain-linked, commercial	foot	20	3800	6.45	24510
Sediment Basin	Trench with drainpipe	acre	20	20	540	10800
Subtotal						161110
Paving						
4" asphalt over staging	2" asphalt over 8" gravel	acre	10	15	62920	943800
2" over the remainder	4" asphalt over 8" gravel	acre	10	5	72600	363000
4" over total area	4" asphalt over 8" gravel	acre	10	20	72600	1452000
	6" concrete	acre	15	20	145200	2904000
Machinery and Equipment						
Water pump	water pump	each	10	1	450	450
Front-end loader	With 3 yd bucket	each	10	1	112000	112000
Compost turner		each	10	1	129000	129000
Thermometer	6′ industrial	each	10	20	200	4000
Scale	Above-ground, installed	each	20	1	15000	15000
Subtotal						260450

Table A-9b. Annual fixed costs for 200,000-ton medium-tech facility

Item	Description	Depreciation	Interest (simple 8%)	Insurance (1% rate)	Repairs (1% rate)	Total cost
Land	Original farmland	-	1984	-	-	1984
Improvements	Grading 1.5%	5050	8080	1010	1010	15150
Fencing	8′ chain-linked, commercial	1226	1961	245	245	3677
Sediment basin	Trench with drainpipe	540	864	108	108	1620
Subtotal						22431
Paving	2" & 4" asphalt	130680	104544	-	13068	248292
	4" asphalt	145200	116160	-	14520	275880
	6" concrete	193600	232320	-	29040	454960
Machinery and Equipment						
Water pump	Water pump	45	36	4.5	4.5	90
Front-end loader	With 3 yd bucket	11200	8960	1120	1120	22400
Compost turner		12900	10320	1290	1290	25800
Thermometer	6′ industrial	400	320	40	40	800
Scale	Above-ground, installed	750	1200	150	150	2250
Subtotal						51340

Table A-9c. Annual labor and machinery operating costs for 200,000-ton medium-tech facility

Annual Labor and Machinery Operations

Operation	Item	Labor (hrs)	Machinery (hrs)
Receiving	Scales	520	-
Staging	Front-end loader	320	320
Creating windrows	Front-end loader	500	500
	Water pump	500	500
Turning windrows	Compost turner	2592	2592
Removal of final product	Front-end loader	250	250
Total		4682	4162

Annual Variable Costs

Item	Unit	Cost per unit	Qty	Total cost
Water	gal	0.0045	4000000	18000
Water pump	hr	1.14	500	570
Front-end loader	hr	16	1070	17120
Compost turner	hr	26	2592	68636
Labor	hr	20	4682	93640
Total				197966

Table A-10a. Capital costs for 200,000-ton medium-S facility

Item	Description	Unit	Life	Qty	Cost per unit	Total cost
Land	Original farmland	acre	-	20	1240	24800
Improvements	Grading 1.5%	acre	20	20	5050	101000
Fencing	8′ chain-linked, commercial	foot	20	3800	6.45	24510
Sediment Basin	Trench with drainpipe	acre	20	20	540	10800
Sub-total						161110
Paving						
4" asphalt over staging	2" asphalt over 8" gravel	acre	10	15	62920	943800
2" over the remainder	4" asphalt over 8" gravel	acre	10	5	72600	363000
4" over total area	4" asphalt over 8" gravel	acre	10	20	72600	1452000
	6" concrete	acre	15	20	145200	2904000
Machinery and Equipment						
Water pump	water pump	each	10	1	450	450
Front-end loader	With 3 yd bucket	each	10	1	112000	112000
Compost turner		each	10	1	129000	129000
Screening system		each	10	1	67150	67150
Shredding system		each	10	1	90950	90950
Thermometer	6′ industrial	each	10	20	200	4000
Scale	Above-ground, installed	each	20	1	15000	15000
Subtotal						418550

Table A-10b. Annual fixed costs for 200,000-ton medium-S facility

Item	Description	Depreciation	Interest (simple 8%)	Insurance (1% rate)	Repairs (1% rate)	Total cost
Land	Original farmland	-	1984	-	-	1984
Improvements	Grading 1.5%	5050	8080	1010	1010	15150
Fencing	8′ chain-linked, commercial	1226	1961	245	245	3677
Sediment basin	Trench with drainpipe	540	864	108	108	1620
Subtotal						22431
Paving	2" & 4" asphalt	130680	104544	-	13068	248292
	4" asphalt	145200	116160	-	14520	275880
	6" concrete	193600	232320	-	29040	454960
Machinery and Equipment						
Water pump	Water pump	45	36	4.5	4.5	90
Front-end loader	With 3 yd bucket	11200	8960	1120	1120	22400
Compost turner		12900	10320	1290	1290	25800
Screening system		6715	5372	672	672	13430
Shredding system		9095	7276	910	910	18190
Thermometer	6′ industrial	400	320	40	40	800
Scale	Above-ground, installed	750	1200	150	150	2250
Subtotal						82960

Table A-10c. Annual labor and machinery operating costs for 200,000-ton medium-S facility

Annual Labor and Machinery Operations

Operation	Item	Labor (hrs)	Machinery (hrs)
Receiving	Scales	520	-
Shredding	Shredder	40	40
	Front-end loader	40	40
Staging	Front-end loader	320	320
Creating windrows	Front-end loader	500	500
	Water pump	500	500
Turning windrows	Compost turner	2592	2592
Screening	Screening system		16
Removal of final product	Front-end loader	225	225
Total		4737	4233

Annual Variable Costs

Item	Unit	Cost per unit	Qty	Total cost
Water	gal	0.0045	4000000	18000
Water pump	hr	1.14	500	570
Front-end loader	hr	16	1085	17360
Compost turner	hr	26	2592	68636
Screening system	hr	6	16	93
Shredding system	hr	12	40	464
Labor	hr	20	4737	94740

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