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ECONOMIC ANALYSIS

A ROUGH GUIDE TO ANAEROBIC DIGESTION COSTS AND MSW DIVERSION

Using generic data from manufacturers and planning assumptions, communities and project developers can get a sense of capital and operation and maintenance costs for an anaerobic digestion facility to process either mixed or source separated residential MSW.

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WHILE industry observers may generally agree that the organics fraction must represent an integral component of any strategy designed to increase residential waste diversion rates, there is less certainty as to what constitutes a cost-effective and technically viable approach. Though a mere blip on the radarscope of North American authorities responsible for municipal solid waste (MSW), anaerobic digestion (AD) appears to be one part of the solution if its growing record of success in Europe is any indication of possible performance on this side of the Atlantic Ocean. Interest in AD is based on its potential capacity to reduce the amount of waste that needs to be landfilled while generating marketable by-products, such as a compost-like digestate that could be blended with other material to produce a soil conditioner and methane gas that can be used as a source of energy. In order to move the concept of AD capacity in North America forward, two immediate challenges are apparent: first, to confirm its technical efficacy with regard to source separated organics (SSO) and mixed waste streams and second, to quantify the costs and benefits on the basis of conventional units of measurement (e.g. cost per ton of design capacity).

Developing a guide to "ballpark" AD capital and annual costs as well as diversion impacts for a range of waste flows and community sizes is the focus of this article. We emphasize the "rough guide" nature of this tool because it is based on equal measures of generic cost data provided by AD manufacturers and planning assumptions, a necessity born out of the general lack of AD capacity on this continent for MSW. Published sources provide some indication of European costs, though continental differences in local waste management conditions coupled with a degree of uncertainty as to what is and is not included in published figures renders the transferability of these costs doubtful. It is important to recognize that actual capital and annual costs for any individual AD system could vary from the rough figures developed in this analysis by as much as –20 percent to + 50 percent depending on the technology, the competitive nature of bids and detailed plant specifications.

CAPITAL COST ESTIMATES

Capital cost estimates — which include AD equipment, building construction and site work but exclude the price of land as well as costs associated with the acquisition of vehicles designed to collect SSO — were developed for a range of facilities that process either residential SSO or mixed waste. The capital cost of an SSO facility varies between $635 and $245/ton of design capacity for plants between 10,000 and 100,000 tons/year (tpy). The capital cost of comparably sized mixed waste facilities is approximately five to ten percent higher, ranging between $690 and $265/ton of design capacity. This difference in capital costs reflects an assumption that a mixed waste AD plant would incur extra costs for a sorting system designed to improve the quality of incoming waste before it is fed into the reactor along with additional floor space inside the building to accommodate this equipment and manual sorters. Costs for manual picking stations, mechanical sorting equipment, conveyors, platforms and chutes have been incorporated into our conceptual design of a mixed waste plant in order to maximize the removal of contaminants and the possibility of producing a marketable soil conditioner. These extra costs are partially offset by potential savings achieved through the purchase of relatively less reactor capacity owing to a higher percentage of residue that is removed before waste is fed into the reactor.

ANNUAL COST ESTIMATES

Net annual costs (including capital depreciation and interest, operating expenses, labor and revenue) range between $107 and $46/ton of design capacity for SSO plants that process 10,000 to 100,000 tpy, respectively. The net annual cost of mixed waste facilities is, on average, approximately 30 to 35 percent higher, ranging between $135 and $63/ton of design capacity. The key components of these cost estimates are summarized in Table 1 for three plant sizes followed by a brief description of the underlying planning assumptions.

Annualized capital costs, which include equipment and building but exclude land and collection vehicles, were calculated at seven percent interest with a 15-year amortization period for AD equipment and 20 years for buildings, based on typical combinations of private and public sector approaches to capital financing. Estimates for mixed waste plants include pretreatment sorting equipment amortized over ten years. SSO plant Operations and Maintenance (O+M) includes O&M costs associated with the AD equipment and building. Relatively higher O+M costs on a per ton basis are anticipated for mixed waste plants, in part, because they include expenses associated with an extensive mechanical and manual sorting system that would not likely be built into a plant that processes SSO.

The cost of residue disposal in an SSO facility was calculated to be $8/ton of design capacity. This figure is based on the assumption that 80 percent of the annual tonnage processed at an SSO plant would be diverted from disposal, primarily through the production of finished digestate and moisture content loss, while 20 percent of the annual tonnage would be removed as residue prior to reactor loading and oversized particles screened out during the curing process. The cost of residue disposal at a mixed waste facility was estimated to be $15/ton of design capacity. This cost estimate assumes that 62 percent of the annual tonnage processed at a mixed waste plant would be diverted from disposal with the remaining 38 percent collected as residue during pretreatment and postreactor aerobic curing. For both types of plants, the cost of residue disposal, including hauling, is assumed to be $40/ton.

Digestate removed from the reactor would likely need to be cured before it could be considered as a marketable product or a material used to produce a blended soil conditioner. Approximately 40 to 45 percent of the tonnage delivered to an SSO plant would require curing while 30 to 35 percent of all delivered material to a mixed waste facility would require postreactor aerobic treatment. Assuming that the curing process costs $15/ton of unfinished digestate, the average cost of curing is estimated to be $7/ton of design capacity at an SSO facility and $6/ton at mixed waste plants.

Table 1 calculations include a 15 percent profit margin on capital and operating expenses. This margin was included to anticipate plant operation by a private sector firm. If the plant were operated by a public sector agency, the profit allowance would no longer be included, though estimates may need to be adjusted for different pay scales and overhead.

Annual production of finished digestate is

Interest in anaerobic digestion is based on its potential to reduce the MSW to be landfilled while generating a compost-like digestate for blending into a soil conditioner and methane gas for energy.

Table 1. Estimated net annual cost of SSO and mixed waste AD plants for three communities (U.S. dollars/ton design capacity)

Cost Item	*10,000 tpy*		*50,000 tpy*		*100,000 tpy*	
Annual Costs	SSO	MW	SSO	MW	SSO	MW
Anualized capital[1]	$68	$74	$33	$37	$26	$29
Plant O+M[2]	$18	$28	$9	$13	$7	$10
Residue disposal	$8	$15	$8	$15	$8	$15
Aerobic curing	$7	$6	$7	$6	$7	$6
Sub-total	$101	$123	$57	$71	$48	$60
Profit (15%)	$15	$18	$9	$11	$7	$9
Gross Annual Cost	$116	$141	$66	$82	$55	$69
Revenue						
Sale of finished digestate	-$2	-$1	-$2	-$1	-$2	-$1
Methane gas sales	-$7	-$5	-$7	-$5	-$7	-$5
Net Annual Cost	$107	$135	$57	$76	$46	$63

[1]Includes capital depreciation and interest.
[2]Includes labor.

Annual tonnage of finished digestate is estimated to be 35 to 40 percent of all source separated organics delivered to an anaerobic facility.

Table 2. Cost and diversion impacts of anaerobic digestion in three Canadian communities

Planning Variables	Satellite City	Midsize City	Metro Area
Description			
Population	162,000	650,000	1,400,000
Current waste diversion rate	37%	24%	30%
SSO AD Plant Assumptions			
Annual recovery rate (lbs/SF hh/yr)	400	400	400
SF homes in housing stock	86%	75%	66%
Single-family dwellings	47,300	195,100	384,800
Tons processed per year	9,500	39,000	77,000
AD plant design (tpy)	10,000	40,000	80,000
AD capital cost	$6,400,000	$13,400,000	$20,800,000
Net annual costs	$1,000,000	$2,300,000	$3,700,000
Tons diverted through AD	7,600	31,200	61,600
Cost per ton processed	$107	$60	$48
New community diversion rate	50%	38%	42%
Mixed Waste AD Plant Assumptions			
Annual residential waste disposal (tpy)	36,600	159,500	357,000
AD plant capacity (tpy)	40,000	160,000[1]	360,000[2]
Capital cost	$14,400,000	$45,200,000	$97,500,000
Net annual costs	$2,900,000	$10,500,000	$22,800,000
Tons diverted through AD	22,600	98,900	221,300
Cost per ton processed	$78	$66	$64
New community diversion rate	76%	71%	73%

Note: Figures may not sum due to rounding.
[1]Costs assume two 80,000 tpy facilities with no economies of scale for multiple plant construction.
[2]Costs assume four 90,000 tpy facilities with no economies of scale for multiple plant construction.

estimated to be 35 to 40 percent of all SSO tonnage delivered to the plant and 20 to 25 percent of all material delivered to a mixed waste facility. Depending on the quality of the finished product, its aesthetic features and the plant's capacity to produce a consistent product that meets the needs of the target market (e.g. premium retail bagged market, bulk sales to residential customers, etc.), finished digestate could generate a revenue stream. For this analysis, a conservative approach assuming a $5/ton value for finished digestate was used because of the uncertain capacity of AD to produce a consistently marketable soil conditioner. On a per ton of design capacity basis, revenue estimates are about $2 and $1/ton for SSO and mixed waste plants, respectively. When more full-scale plants are in operation in North America, these revenue assumptions can be modified.

One of the advantages of anaerobic digestion of residential waste is the potential to earn revenue from the sale of surplus methane gas, electricity and/or steam generated by the facility. For the sake of simplicity, this analysis focuses on the production of surplus methane gas to estimate potential revenue. It should be noted, however, that this scenario might not be viable for all AD facilities, as the gas user needs to be located close to the digester. Surplus methane also could be used to generate steam for sale to proximate customers or to generate electricity that is sold into the local grid as "green power."

Biogas yields are estimated to be about 115 and 95 cubic meters per ton of design capacity for SSO and mixed waste plants, respectively, with a 55 percent methane gas content. (A lower yield for mixed waste was assumed because this fraction contains a higher percentage of material that degrades at a slower rate than the food-rich SSO stream.) On-site utilization to meet the energy needs of the AD plant is assumed to represent 25 percent of total methane gas production. Based on these figures, the production rate of surplus methane gas is estimated to be about 40 cubic meters per ton of design capacity at an SSO plant and 30 cubic meters per ton at a mixed waste facility. Methane is assumed to generate revenue of $0.18 US/cubic meter, which is representative of the market price in the Toronto, Canada area. Assuming that this price is indicative of markets across the continent, potential revenue from the sale of surplus methane gas is estimated to be approximately $7/ton of design capacity for an SSO plant and $5/ton at a mixed waste facility.

THREE SCENARIOS

To illustrate the potential impacts associated with AD processing, separate cost and diversion estimates were developed for SSO and mixed waste options for three Canadian communities: a rapidly growing satellite city, a midsize city and a metropolitan area. Each community differs in terms of population, current residential waste diversion rates and number of single family households as a percentage of the total housing stock. Capital cost estimates for each community were calculated by multiplying the suggested design capacity by the corresponding unit cost (e.g. 10,000 tpy × $635 ton). The estimated number of tons to be processed in each community (i.e. organics recovery for SSO plants and total residential waste disposal for mixed waste facilities) was multiplied by the appropriate unit cost to approximate net annual costs (e.g. 36,600 tpy × $78/ton). The analysis of SSO processing assumes an average recovery rate of 400 pounds/single family household/year, a figure that could vary significantly in individual communities depending on the range of targeted organic materials.

Table 2 shows that implementation of an SSO program in the single family housing sector could lead to significant increases in overall diversion (given the challenges associated with separating organics in multifamily buildings, an SSO program designed exclusively for single family households was assumed). Data for the satellite city, for instance, suggest that the city's overall residential diversion rate could increase from 37 percent to 50 percent. For both large cities, new city wide diversion rates are estimated to be 38 percent and 42 percent, figures that fall below the 50 percent threshold partly because of the relatively low proportion of single family households. Estimates for the mixed waste option — which targets both single and multifamily dwellings — suggest that each community could divert at least 70 percent of its residential waste, though at a considerable cost.

The cost and waste diversion estimates developed for this analysis are contingent upon a number of planning assumptions that may not be indicative of local conditions across the entire North American continent. Variables that should be assessed in order to develop a range of figures that better reflect local conditions include: Quantity of organic material in the waste stream; Range of organic materials be targeted for SSO collection and processing; Potential SSO recovery rates; Number of single family dwellings; Residential waste disposal rates (for both single and multifamily households); Landfill tip fees; Waste hauling costs; Markets for methane gas, electricity and steam; Compost revenue; and State guidelines regulating the use of a soil conditioner made from MSW.

CONCLUSION

This analysis presented figures that could be used to calculate "ballpark" capital and annual cost estimates for a range of AD plant sizes and waste flows. While these figures are intended to represent the generic cost of AD implementation and operation, they do not capture the entire scope of possible cost implications of moving to an organics strategy. Implementation of an SSO program could, for instance, require substantial changes to the existing residential garbage and recycling collection system. Depending on the current level of service and the preferred future option, an SSO program could require the acquisition of a new fleet of collection vehicles (e.g. cocollect organics and garbage in a two compartment vehicle), the reconfiguration of collection routes based on new productivity rates and an extensive promotion, education and outreach campaign.

Implementation of AD capacity could lead to substantial increases in residential waste diversion, with Table 2 figures suggesting the possibility of a 50 percent citywide diversion rate with SSO plants and rates that exceed 70 percent if mixed waste from both single and multifamily households were collected for processing. The initial attractiveness of AD in general and the mixed waste option in particular needs to be balanced against the relatively high capital and annual cost as well as the risk associated with a technology that has yet to be implemented in a North American municipal waste management setting. However, this should not discourage municipalities considering an organics strategy from including anaerobic digestion in their evaluation of waste management options. The technology has significant advantages, including a small footprint requirement and the potential to generate "green" energy, which is a commodity of value with the opening up of many state energy markets. The potential for greenhouse gas (GHG) emissions trading also provides AD with an edge, and another possible source of revenue. A company that produces "green" power would, for instance, be allotted a number of marketable credits that could be purchased by firms (usually large polluters) that want to reduce emissions without implementing changes to their production facilities. An international market for GHG credits is gaining credence as witnessed in 1999 by Ontario Power Generation Inc.'s payment of $25 million to a U.S. a firm for rights to 2.5 million tons of carbon dioxide.

The determination of which AD option may be most appropriate for any given municipality will vary with the local conditions, a community's broad waste and environmental goals and willingness to accept the relative advantages and disadvantages inherent in SSO versus mixed waste AD processing. Communities that face severe landfill disposal problems may prefer the mixed waste option because of its considerable waste diversion potential while placing less emphasis on potential revenue through the sale of finished soil conditioner or surplus energy. In contrast, municipalities with a well-developed waste diversion infrastructure may decide that the production of marketable products and surplus energy is an appropriate balance if overall waste diversion reaches the 50 percent level. Municipal leaders contemplating AD strategies should visit plants in Europe where the technology is now well established in order to gain a first-hand understanding of this potentially important and environmentally responsible approach to waste diversion. ■

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