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Anaerobic Digestion—What Are the Economics?

Although solid waste AD facilities are just starting to emerge, haulers and their customers may see some benefits if the development trend continues. A Pro Forma Model objective can be constructed for strategic planning of an anaerobic digestion facility.

■ By Marc J. Rogoff, Ph.D. and Bruce J. Clark, P.E.

Anaerobic digestion (AD) of food wastes in the U.S. is a developing market that is poised for continued growth in many regions. Although solid waste anaerobic digestion facilities are just starting to emerge, haulers and their customers may see some benefits if the development trend continues. This article discusses what an anaerobic digestion plant does, and what the authors see as the economics where they recently have been installed and are operating.

Anaerobic Digestion

Anaerobic digestion is the bacterial breakdown of organic materials in the absence of oxygen. This biological process produces a gas, sometimes called biogas, principally composed of methane (CH₄) and carbon dioxide (CO₂). The anaerobic process is most often used to treat organic wastes other than unsegregated MSW, such as sewage sludge (biosolids produced from treated sanitary sewage at a wastewater treatment plant), yard vegetation, agricultural wastes (both animal and plant) and some industrial waste sludge. Depending on the waste feedstock and the system design, biogas is typically composed of 55 to 75 percent methane. The anaerobic digestion process occurs in three steps:

1. Decomposition of plant or animal matter by bacteria into molecules such as sugar.
2. Conversion of decomposed matter to organic acids.
3. Organic acid conversion to methane gas.

AD can occur naturally in a landfill or in a controlled environment such as a manufactured chamber or vessel. In an AD facility, the incoming waste stream is initially processed for removal of potential contaminants, reduced in size and delivered to an air-tight reactor vessel, typically called a “digester”. AD facilities are usually classified based on whether the system uses a single reactor or multi-reactor system, and if water is added for processing (wet systems) or absent during processing (dry systems).

There are more than 200 AD facilities around the world with operating capacities greater than 2,500 tons per year (TPY). These plants process not only the organic fraction of the MSW waste stream, but also organic waste from food industries and animal manure. Europe leads in the number of AD plants and total installed capacity principally due to the European Union Directive that requires member states to reduce the amount of landfilled organics by 65 percent by 2020.

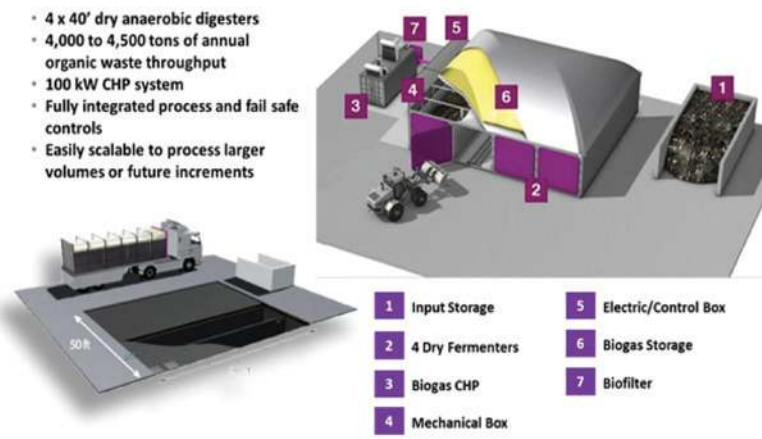


Figure 2 Illustrative schematic of the SmartFerm System. Figure courtesy of Zero Waste Energy, LLC.



Figure 1: Last of four digesters installed in place. Figure courtesy of Jeff Lindenthal, Monterey Regional Waste Management District, 2013.



Figure 3: Digester bays of the Marina, CA AD facility. Figure courtesy of Jeff Lindenthal, Monterey Regional Waste Management District, 2013.

Technology Vendor	Customer	Location	Current Capacity (tons per year – TPY)	Start-Up
BioFERM	University of Wisconsin, Oshkosh campus	Oshkosh, WI	6,000	2011
Zero Waste Energy	Monterey Regional Waste Management District	Marina, CA	3,000	2013
Zero Waste Energy	Zero Waste Energy Development Company	San Jose, CA	90,000	2014

Table 1: Operating “dry” AD systems in North America. Tables courtesy of SCS Engineers.

Item	Cost (\$)
Digester Components (Leachate collection slab, gas collection bag, heating elements, gas piping, etc.)	1,000,000
Building Superstructure	575,000
Engine Generator Set	200,000
Improved Base for Foundation	200,000
Mixing Platform	100,000
Biofilters	100,000
Food Storage Pad	50,000
Electrical Interconnection	75,000
Design, Permitting Support and Fees	50,000
Contingency	100,000
Total 2,450,000	

Table 2: Conceptual AD plant estimate (5,000 TPY Capacity).

There are more than 120 plants processing about 4.6 million tons per year of organic fraction of MSW in Europe.

The “dry” system technology has been adapted to manage parts of the municipal solid waste (MSW) stream and is the current preferred technology in the U.S. for processing of organics in typical MSW. Currently in North America there are four commercially operating “dry” AD facilities, where the feedstock is primarily organics from MSW (see Table 1).

SmartFerm Anaerobic Digesting System

The Monterey Regional Waste Management District (MRWMD) AD system was developed by Zero Waste Energy, LLC (ZWE). ZWE is a San Jose, CA-based company that holds the exclusive U.S. license to construct and operate the German “SmartFerm™” AD technology developed by Eggersmann Anlagenbau GmbH Group of Germany (EAB). This technology is widely used in Europe and is currently used at the MRWMD’s Marina facility and at a similar, but larger plant in San Jose.

ZWE’s SmartFerm, dry anaerobic digestion system is reported to contain the following design and processing features:

- The digesters are pre-fabricated chamber “modules” that can be grouped together to provide required processing capacity (Figure 1).
- The digester operates in the thermophilic range (125 to 131° F) for optimum gas production. The average retention time in the digester is 21 days.
- Percolate (recycled leachate) is used to keep the pile at the proper moisture content. Dry solids can be in excess of 50 percent of the organic waste input.
- Digesters are biologically self-heated through the air system and re-circulation of the liquid percolate through the material.

- This liquid percolate contains the necessary thermophilic biological constituents. Partially digested recycled material is not needed to inoculate subsequent batches.

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Table 3: General assumptions for Pro Forma Model.

Variable	Value	Comments
Base Year	2014	Costs estimates were made in current 2014 dollars and escalated based on the inflation factor identified below
Inflation Rate – Annual Escalation (for Energy, Labor, and Waste Collection)	2%	Based on recent Federal Reserve Board guidance
Organic Waste Received (Tons Per Year)	5,000	Based on model developed by ZWS
Annual Operating Costs (\$)	3% of Capital	Estimated from information provided from AD developers
Annual Capital Repair and Replacement	1% of Initial Capital	Estimated from information provided from AD developers
Financing Cost	Interest Rate: 3.35% Term (Years): 20	Agency borrowing costs
Tipping Fees	\$35.00 per ton	Assumed
Energy Sales Prices	\$0.1044 per kilowatt hour	Assumed retail purchase price
Sale of Digestate	\$0.00 per ton	Wholesale compost rates

- These AD plants require a smaller footprint than traditional wet anaerobic systems.
- Following digestion, the residual is moved to another chamber where the material is partially composted using forced air. After approximately four days this material is removed and put into outside windrows to complete the composting process.
- Odors are minimized because the entire facility is enclosed and process air is circulated through a biofilter.
- The digestate emerging at the end of the process is free of pathogens (per U.S. EPA’s Process to Further Reduce Pathogen’s requirements).

The SmartFerm AD facility includes the following four major process phases described below and depicted in **Figure 2**:

1. *Supply Air and Aeration*—Once the organic wastes are loaded into a digester, a hatch door is closed using a gas seal to ensure that biogas cannot escape. Each digester contains an in-floor aeration system, which is activated once the door is sealed. This aeration system pumps air from outside into the organic waste to help create aerobic digestion conditions that self-heat the material to designed process conditions for the first 12 hours. A mixture of oxygen and methane is potentially combustible so the chamber air is purged to remove any remaining oxygen before the anaerobic cycle commences.

2. *Percolate Cycle*—Under anaerobic conditions, the waste materials are sprayed with conditioned process water containing thermophilic microorganisms (percolate) that begin the decomposition process and produce biogas. This percolate is pumped in a closed loop between the digesters and the heated and insulated percolate tanks located beneath the digester units. Percolate continues to be sprinkled on the waste materials for approximately 20 days, causing the production of biogas. Percolate is collected in a drainage system, screened for solids and pumped back into a percolate tank where it is recharged with thermophilic organisms. Process control instrumentation ensures proper control of the percolate tank and regulation of percolate temperature.

3. *Biogas System*—Biogas from each digester is pumped to the percolate tank to obtain a rich, homogenized biogas, then pumped to a roof-top, double-membrane storage bladder. The stored biogas is then combusted in a power plant or compressed into natural gas (CNG) for future uses.

4. *Exhaust Air*—On the 21st day of processing (and before the digester doors are opened) ambient air within the digester is collected in an exhaust piping system. Low quality biogas (less than 20 percent methane) is combusted and the digester air is transferred to a biofilter for treatment.

The MRWMD Marina AD facility became officially operational on March 8, 2013 when the first bay of the digester was filled (**Figure 3, page 22**). Since that time, all of the digesters have been filled, emptied and refilled. During the AD process, biogas has been produced and collected in the storage reservoir, which is located above the digesters. On April 2, 2013, the engine generator became operational, producing the design 100kW of electricity. According to MRWMD officials, work continues to optimize the raw material mix and loading/unloading of the digesters to minimize odors and achieve the best operational mix for the pilot facility.

Pro Forma Model
Capital Costs

For preliminary economic modeling purposes, the AD facility was assumed to consist of a variety of processes and systems including the following:

- Waste receiving building and storage area
- Waste processing and preparation
- Fermentation
- Digestate dewatering and curing
- Biogas treatment
- Energy production
- Odor control (biofilters)

ZWE was contacted in order to develop an estimated range of capital costs for the proposed AD facility. The submitted cost estimates were reviewed, adjusted as appropriate for project specifics and used on an aggregated basis. The adjusted estimates ranged from \$2 to \$4 million. These were planning level estimates and the actual cost of an AD facility could vary significantly from these estimates.

An AD system cost of \$2,450,000 was assumed in the base case to evaluate project feasibility (**Table 2, page 23**). Additional sensitivity analysis can be conducted to evaluate the impact on capital costs on the overall project economics, if necessary, based on the selected area of the property for project development. For initial construction costing, we have assumed that the proposed site for the AD facility would not require extraordinary foundation design and construction modifications.

Typically, the conceptual design for an AD facility assumes that electricity would be produced for onsite uses, as well as for export to the grid. This would require an interconnect with the local utility, which would enable the AD facility to transfer electrical power to nearby facilities to offset retail purchases,

Table 4: AD model results.

Scenario	Tonnage	Electricity Production	Required Tipping Fee Range
1	5,000	None	\$45.92 - \$53.16
2	5,000	203 Kwh/ton @\$0.1044 used onsite	\$8.76 - \$31.97
3	10,000	None	\$40.73 - \$48.53
4	10,000	203 Kwh/ton @\$0.1044 used onsite	\$3.57 - \$27.34

sell electrical power to the local utility and to purchase standby power when the onsite power generation system is not in operation.

We have assumed that the partially composted digestate will be delivered to a composting site with nominal processing and additional cost. The conceptual cost estimate includes a chamber process air removal system and an outdoor wood chip biofilter. Operating costs were assumed to include all labor, fuel and materials associated with the operating AD facility. Estimated labor assumes two to three full-time facility employees (plant manager, heavy equipment operator and maintenance staff).

General Assumptions for Pro Forma Model

In order to evaluate the proposed project revenues, costs savings and expenses, a number of assumptions were made as shown in Table 3.

Model Results

A series of four model scenarios were developed to determine the financial impact to the AD project if the tonnage to the facility was increases, if the biogas was beneficially used to generate revenue or offset electricity costs. Table 4 shows the tipping fee range that would be necessary to operate the system.

Potential Feasibility

The economic Pro Forma, in this case, projected the need for an additional subsidy (in addition to the normal landfill tipping fee) to make up for the low revenue streams of electricity and digestate/compost sales. That being said, this is not to say that all facilities would require a tipping fee of around \$70 per ton to become economically feasible. Relatively lucrative revenue streams can come from traditional sources such as an onsite energy user (“self-service wheeling”, which would possibly defer high retail purchase prices for power).

Furthermore, the consultants have conducted similar feasibility assessments in areas where Renewable Energy Credits (RECs) are available and these revenue supplements definitely result in AD projects with reasonable payback periods and return on investments for their developers.

A Shift in the U.S. Market

Could AD become more widespread as a viable solid waste disposal option? As this overview discussed, there are many factors, singularly or a combination, that would seem to converge for the potential to be there including: significant centralized source of high quality organic waste, relatively high power costs and utility economic incentives, limited land suitable for composting, lack of conventional waste-to-energy facilities, markets for the residual compost and/or a ban on organics disposal in landfills.

Several AD facilities using food scrap waste are operational and appear to be providing good performance. AD process system vendors, mostly from Europe, are sensing a shift in the U.S. market and are establishing bases here. The technology is adapting to our market with pre-engineered, plug and play type systems being perfected.

Although solid waste AD facilities are just starting to

emerge, haulers and their customers may see some benefits if the development trend continues. With separated organic wastes, haulers could have another specialty market to serve, and also help customers transition to separating more organic waste from their garbage and potentially lowering their overall disposal bill. | **WA**

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