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Waste In, Energy Out: The Costs and Benefits of Anaerobic Digesters

Anaerobic digestion is a proven technology, but what are the economic benefits?

Daniel P. Duffy • December 15, 2016

Credit: Cornerstone Environmental Group

Anaerobic digesters are a mature, proven technology. They take sludge, manure, and other organic waste materials and produce methane (natural gas) fuel. Nobody questions their technological capabilities. However, the question remains as to their economic benefits. In terms of dollars and cents, how much economic sense do anaerobic digesters make? What are the economic benefits of an anaerobic digester fuel system? Under what scenarios do they make sense, and under what scenarios are they of only marginal benefit—or should not be considered at all?

As a source of renewable energy, how is this energy applied? Can anaerobic digesters be used economically to provide grid-ready electrical power, or should they only be used to provide fuel for local, niche applications?

The answers to these questions will determine the extent at which anaerobic digesters can contribute to our nation's energy needs.

Anaerobic Digester Design and Operation

Anaerobic digestion is a naturally occurring process that can be harnessed to transform organic waste into a mix of methane gas and carbon dioxide (usually referred to as "biogas"). Several types of bacteria are involved in the anaerobic digestion process, and they, in effect, take turns during the process with the first types preparing the way for successor microorganisms. First-stage bacteria break down carbohydrates during bacterial hydrolysis to produce soluble materials such as sugars and amino acids that can be consumed by the next set of microorganisms, the acidogenic bacteria. These consume the biomass and convert it into carbon dioxide, hydrogen, ammonia, and miscellaneous organic acids.

These are, in turn, converted into acetic acid. Lastly, anaerobic methanogenic archaea bacteria convert these residual products into methane and carbon dioxide (biogas). In addition to biogas, digesters produce a condensate liquid (referred to as "digestate" consisting of water, minerals, and the bulk of the residual carbon from the original organic material. Digestate is often used as high-quality liquid fertilizer.

Anaerobic digesters operate in one of three temperature regimes: thermophylic (120–140°F), mesophylic (95–105°F), and psychrophylic (60–75°F). Large-scale, centralized, commercial biogas facilities usually operate in the thermophylic range. The higher heat allows the systems to operate at greater efficiency, handling more organic material in less time as the rate of bacterial activity increases with temperature. This increased efficiency can reduce digester retention times to as low as 3–5 days. Additional heat also increases the kill rate of unwanted pathogens. However, more heat energy is required to operate the system, which also requires extensive insulation to retain this heat. The heat can be applied by an external heat exchanger or as part of a combined heat and power system utilizing excess heat from other facilities.

Operating at lower temperatures, mesophylic systems require longer digester retention times of more than 20 days. Smaller, midsized operations utilize mesophylic temperatures, but can utilize specially shaped chambers to concentrate organic solids and indirectly increase operational efficiency. Small-scale operations, where production rates and retention times are less important, operate at the relatively inexpensive psychrophylic range. This is the least efficient, but is also the simplest, least-expensive digester system.

Though anaerobic processes occur in nature (at the bottom of stagnant ponds and producing “marsh gas”), man-made systems utilize container vessels to hold both the organic material and its host bacteria. There are two broad categories of anaerobic digester operations: wet and dry. Wet digesters include plug flow and completely mixed operations.

Plug flows are used for drier (11–13% solids content) and thicker organics such as manure. Organic materials are fed into a hopper and forced into long pipelines and channels that constantly feed the material into the digester chambers as a continuous production process. These digesters can be configured horizontally or vertically. Flow is mainlined either by the force of gravity, push paddles, or hydraulics. The final products include biogas, compost, and liquid digestate.

Completely mixed digester operations mix new material with previously digested material as partial or complete batch run processes. The material used by mixed operations is wetter (only 4–12% solids content) and often utilized recirculated digestate. The complete mixing process has to be very thorough to prevent he formation of a floating layer of oils and fats from accumulating at the top of the digester contents. The design of a complete mix digester also has to allow for removal of bottom grit. This usually requires the addition of routing scraper arms deployed across the tank bottom to push grit to the removal port. Operating pressures and flammability are also potential problems, necessitating the addition of pressure relief valves, flame arresters, vacuum breakers, blower, and fans.

The entire anaerobic digestion system requires integrated tanks, mixers, covers, and heating systems. Usually a complete mix digester utilize only one large tank. Inside this tank all the phases of digestion occur (mixing, addition of moisture, hydrolysis, methane production and extraction, etc.). Depending on their size and required throughput capacity, multiple digester tanks can be utilized in parallel to increase the overall production rate. Mixing is usually continuous and can be performed by injecting biogas back into the organic material, hydraulically by with high-velocity mixing jets, and mechanically with propellers or turning wheels. The digester tanks themselves can be made of reinforced concrete (precast or cast in place), stainless or carbon steel, and have their interiors coated to prevent corrosion with glass or painted epoxy. The circular tanks walls are capped by a tank cover. These covers can be fixed or floating that expand or contract as interior gas pressures change.

Dry digesters utilize batch production techniques to convert organic materials with unprocessed high solids content (15–30% solids). Simple in design, dry digesters are buildings where organic material is stack up in piles of loose piles 10 to 15 feet high by front end loaders. These structures measure up to 15 feet wide by 50 feet long, and are constructed of coated concrete. The organic material is then saturated with digestate to ensure complete bacteriological action. Large voids are maintained (30% by volume). Percolate liquid dripping down though the pile is collected and recirculated by spraying it back into the organic mass. Digestion times are longer than for wet digestion, usually two to four weeks. Both costs, and heat requirements are minimized by dry digesters.

Anaerobic systems are used by farms (mostly to manage manure from livestock), food processing facilities, and by centralized plants that receive shipments from regional and local organic material sources. In addition to maximizing biogas production, other operational concerns include: maintaining a balance between new and processed organics, preserving the correct operational temperature range, prevent plugging of ports and pipelines as well as crusting of interior surfaces, operating and maintaining all safety related systems, and efficiently extracting and storing the biogas.

Operational Costs, Capital Costs, and Profit Potential

A cost benefit analysis of anaerobic digester operations has to take into account several factors. Benefits include: the potential sale of either the biogas itself or the use of biogas to generate electricity which can be sold back to the grid, the resale of digested fiver as compost or liquid digestate as high-quality fertilizer, and the heat generated by the system in the form of hot water circulated by a CHP system.

Capital costs items include: lift station pumps, mixing tanks, the digester tank itself, piping for gas and hot water, gas pumps, flow meters, safety features, generators, electrical wiring and controls as well as power transmission lines, design engineering, and onsite buildings for generators, maintenance, operations, etc. The payback period Capital costs divided by annual net benefits) of this capital investment can be between five and six years ("Benefits, Costs and Operating Experience at Seven New Agricultural Anaerobic Digesters", Moser et. al 1998).

The facilities in this study were farm operations with benefits ranging between $46,000 and $55,000, and capital costs between $240,000 and $289,000. Operating and maintenance costs for the digester and electrical generator can run from 2.3 to 7.0% of total capital costs ("An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities", USDA, October 2007).

Energy production is the main reason for anaerobic digestion operations. The amount of energy depends on both the quantity and kind of organic material being processed. Table 1 summarizes these values.

Table 1. Manure/Energy Estimation

Description	Manure Quantity As Excreted (kg/d)	Biogas Production (m^3/d)	Electricity Potential (kW)/year	Energy Potential (GJ)/year
Beef	24.0	1.10	663	3.0
Dairy	62.0	2.01	1,227	5.5
Piglet	3.5	0.16	98	0.4
Poultry (100 - layer)	8.8	0.85	516	2.3

"Economic Feasibility of Anaerobic Digesters." Alberta Department of Agriculture and Forestry, June 2008.

The resultant cost savings can be calculated as follows. Assuming that the cost of electricity is $0.06 per kilowatt-hour and the price of heat is $5.50 per gigajoule, the annual production of biogas from a dairy operations with 100 cows would be 2.1 cubic meters per day, equivalent to 1,227 kWh or 5.5 GJ annually. Annual electricity cost savings would be $7,362 (100 x $0.06 per kWh x 1,227 kWh) with annual gas savings equal to $3,025 (100 x $5.5 per GJ x 5.5 GJ). This represents a total annual savings of $10,387.

In addition to direct financial consideration, there is considerable overhead generated by legal and management issues: insurance premiums, building permits, design and consulting fees, licensing and zoning, sales agreements with utilities to buy back electricity, siting requirements, odor abatement, noise mitigation, truck queuing, effluent discharge, gas pipeline usage, etc. Interconnection with the local power grid requires both physical hookups, and net metering agreements. There are Federal rebate programs that can help defray many of these costs, but these can require extensive documentation to complete the application. Purchase agreements will also have to be negotiated for the sale of heat to local CHP systems, liquid fertilizer and compost, and tipping fees for trucks shipping organic waste to centralized facilities.

Bioreactor Landfills

For the solid waste industry the largest possible anaerobic digester is the bioreactor landfill. Instead of a digester "tank" with a volume measured in thousands of gallons, a bioreactor landfill operator has an anaerobic digester with a capacity in the range of hundreds of acre-feet. This unique approach flies in the face of received wisdom in regards to the standard methods of dealing with waste disposal.

Credit: Eisenmann Corp.
Digester tanks are made of concrete, stainless or carbon steel.

Standard methods of landfill design, construction, and operation utilize the "dry tomb" approach to waste management. The whole point of the dry tomb approach is to keep moisture out of a landfill. This is done by the installation of a secure final cap and cover system usually consisting of a composite geomembrane and low-permeability soil cap. This system prevents infiltration of precipitation, runoff, and snow melt into the underlying waste mass. In addition, a secure composite liner and leachate collection and management system removes excess liquids from the bottom of the landfill. As a result, very little of the organic component of the deposited waste actually decomposes. In fact, operators that drill landfill gas (LFG) extraction wells into the waste can still read the newsprint and magazines brought to the surface years or decades after.

Contrary to the dry tomb method, the bioreactor landfill deliberately introduces large amounts of water into the deposited waste mass. MSW consists of approximately 62% organic materials by weight (27% paper, 15% food, 14% yard waste, 6% wood), and 38% inorganic (4% glass, 9% metals, 13% plastics, 9% rubber and textiles, 3% miscellaneous; *USEPA MSW Handbook 2013*).

The deliberate addition of water accelerates what is normally a slow decomposition process. The decomposition of organic waste yields significant quantities of LFG (approximately 50% methane, 50% CO2, and various trace gases), even from a dry tomb landfill. The production of LFG is a five-stage process of alternating aerobic and anaerobic decomposition processes that occurs over many years during the landfill's operational lifetime and post-closure care period ("Landfill Gas Management Sources and System Design", a lecture by D. P. Duffy, P.E., Ohio State University, November 2008).

1. *Aerobic Decomposition.* This first stage is driven by aerobic bacteria and begins almost immediately after waste disposal. The waste's organic fraction is subject to both hydrolysis (chemical reactions with moisture and water presenting the waste mass that result in the breakdown of complex organic molecules such as carbohydrates into simpler ones such as sugar), and aerobic degradation. This is an exothermic reaction that raises the temperature of the waste up to 158°F while producing both carbon dioxide and water vapor as the aerobic microbes consume the available oxygen in the deposited waste. Once the oxygen has been almost completely removed, an anaerobic state is achieve and triggers the next stage.
2. *Anaerobic Acidogenesis.* Hydrolysis continues under an anaerobic regime by microbes that are actually poisoned by oxygen. This is a form of fermentation (the process of energy production in a cell in an anaerobic environment) that produces organic acids, hydrogen, carbon dioxide, water vapor, and ammonia nitrogen. The hydrogen and carbon dioxide are produced as byproducts of acidogenesis of the simpler organic monomers previously produced by aerobic hydrolysis (the process converts the simpler molecules into volatile fatty acids). During this stage, sulfur-reducing bacteria produce hydrogen sulfide. Unlike aerobic decomposition, anaerobic decomposition is an endothermic process (requiring heat energy), and the temperature of the waste usually falls.
3. *Anaerobic Acetogenesis.* The conversion of the volatile fatty acids produced by the previous stage's acidogenesis activities into acetic acid, carbon dioxide, and hydrogen occurs in this stage. By this stage, the waste's temperature has fallen to between 68 and 104°F. Though gas production is less than optimal, acetogenesis sets the stage for the landfill's long-term stage of stable LFG production.
4. *Anaerobic Methanogenesis.* The fourth and most productive stage is methanogenesis. (Available acetate is converted to methane and carbon dioxide while using up hydrogen.) The process can also involve carbon dioxide reduction by free hydrogen molecules. This phase is the longest duration, often lasting as long as, or longer than, all the other previous phases combined. The durations of each of the other stages are measured in terms of years—except for this fourth stage, which can last for decades. Settlement of the waste due to decomposition also achieves maximum volume reduction at this time. Production of nitrogen effectively disappears during this stage.
5. *Aerobic Decomposition.* Once all of the available acetate is converted into methane, the landfill is ready to return to its initial aerobic stage. As there is no more feedstock for anaerobic microbes, they're displaced with aerobic microbes. Methane production falls to zero, while the landfill begins to once again emit nitrogen and oxygen. This stage by definition lasts the longest, though most landfills haven't existed long enough for this stage to begin, much less be fully played out.

By deliberately injecting water and air into a waste mass that has been shredded prior to disposal instead of compacted in place, a bioreactor landfill can generate many orders of magnitude more LFG than a standard landfill. During the initial aerobic stage, the looseness of the waste creates a greater surface area for bacteria to do their work, as opposed to tightly compacted refuse. This bacteria is fed by the moisture created by introducing water.

Though there are purely aerobic landfills that utilize injected air and completely remove leachate to achieve aerobic decomposition to simply reduce in-place waste volumes, the most lucrative approach is the anaerobic bioreactor that also maximizes the production of usable methane gas. Instead of removing leachate permanently, an anaerobic bioreactor recirculates the leachate, filling the void spaces of the waste with a continuous supply of liquid and removing air from the waste mass. Like the aerobic bioreactor, anaerobic bioreactor landfill operations shred the waste prior to disposal to maximize effective surface area. This drives the decomposition into the anaerobic methanogenic stage.

Concurrent with the decomposition operations, the operators of bioreactor landfills can perform “landfill mining” operations to remove valuable metals and extract other marketable inorganic materials from inactive portions of the landfill. Between the rapid decomposition, methane production, and landfill mining creating a continuous new supply of available disposal airspace, a bioreactor landfill can act as an “infinite” landfill whose operational lifetime is unlimited and unconstrained by volume and space limits. However, the design and operation of bioreactor landfills can vary significantly from state to state since they often occupy a regulatory gray area.

EPA continues to perform studies concerning the maximizing of the fuel production potential of bioreactor landfills. According to the USEPA Bioreactor Performance Report, areas of ongoing study include

- assessing the state-of-the-practice of bioreactor landfill design, operation, and maintenance;
- identifying case studies of bioreactor landfill use—especially where data exist for comparison between traditional and bioreactor approaches;
- determining long-term monitoring needs for environmental compliance for groundwater, gas emissions, leachate quality, liner stability, physical stability, and other factors to satisfy life-cycle integrity and economic viability concerns;
- exchanging views, technical concerns, and implementation concerns regarding both pending and planned regulations effecting landfills, in general, and the regulatory framework to be developed for bioreactor landfills;
- examining the economic viability, impacts, and benefits of bioreactor landfill implementation at full scale; and
- identifying and prioritizing research and regulatory needs.

Biogas Use and Purification

Small-scale uses of biogas include cooking and illumination. Larger-scale applications use biogas to run a generator turbine for electrical power production, heating/cooling applications for cogeneration systems, and purified to remove its carbons dioxide component and use the methane as a natural gas replacement.

The heat value of biogas is typically 690 BTU/ft^3 or 11,316 BTU/lb. This is significantly less than pure methane, at 1,011 BTU/ft3 or 23,811 BTU/lb., and reflects the quantity of carbon dioxide and trace gases in the biogas. This provides sufficient incentive to purify biogas to increase its potential heat value.

Since LFG and biogas from anaerobic digesters is a mixture of methane and carbon dioxide, it has to be purified by having its carbon dioxide content removed, leaving behind nearly pure methane fuel. Since it is only 50% methane, LFG has only half the BTU value as natural gas fuel—this limits its value for use in power generation and transport. Furthermore, its impurities such as hydrogen sulfide (the source of LFG's "rotten egg" odor) exceeds allowable limits for fuel use, and LFG includes excessive amounts of water vapor inhibiting fuel performance. The purification process is intended to produce a pure stream of methane free of carbon dioxide, chemical impurities, and water vapor. There are several types of purification processes, each involving several steps: solvent absorption, pressure swing absorption, membrane separation, and carbon dioxide absorption.

Solvent absorption is a proven mature technology for removing carbon dioxide from industrial gas streams in general, and biogas in particular. The absorption of carbon dioxide is performed by solvent chemicals as the biogas bubbles through an absorption column filled with the liquid solvents. The absorbed carbon dioxide is later released by heating the solvents to 250°F. This allows for the continuous reuse of the stripping solvents.

Pressure swing absorption is performed at ambient temperatures. Since different gases have differing bonding characteristics with different surfaces, these surfaces are part of absorbing beds through which the gas passes over and through. Absorbing beds with a natural affinity for carbon dioxide are used to extract it from the biogas stream. The absorbed CO_2 can be released by reducing the pressure within the bed's containments chamber, allowing the absorbing material to be re-used.

Often used as an adjunct to other separation methods, membrane separation utilizes porous membranes made from hollow fibers to extract gaseous impurities. Polymer membranes are preferred that can function at 2,000-psi pressure and operating temperatures as high as 400°F. Given their differing molecular weights and structures, different gases permeate across a membrane barrier at different rates. This allows operation to either force through impurities that need removal or retain for sequestration, depending on the gases involved.

A more recent approach is carbon dioxide washing. It takes advantage of the differing chemical triple points (the pressure and temperature where a material transitions from gas to liquid to solid simultaneously). At the same pressure, carbon dioxide freezes at a higher temperature than methane does. So, running biogas up a freezing vent stack causes carbon dioxide to liquefy and fall out of the gas flow in the form of liquid droplets. As the drops falls in the opposite direction as the rising gas, the liquid CO2 removes other trace impurities from the gas stream. Collected at the bottom, the CO2 can be frozen, removed as dry ice, and reused as a refrigerant. The remaining methane escapes out of the top of the freezing stack where it is collected and stored in pressurized tanks as almost pure natural gas.

Is it worthwhile economically to purify biogas, remove its CO2 content, and effectively double its BTU value? That depends on the location of the system, its intended use, and the quantity of biogas being produced. For certain applications, such as the use of compressed natural gas (CNG) as fuel for vehicles and equipment, it is a necessity since natural gas vehicles require pure methane to operate properly. But for other applications, such as the local generation of electricity by small generators, straight biogas may be sufficient.

Industry Leaders
With more than 90 biogas installations worldwide, the Eisenmann Corporation is in the business of providing one-stop shopping for a comprehensive range of advanced, efficient eco-solutions—including anaerobic digester systems. Eisenmann offers horizontal plug-flow digesters, which are especially designed for processing waste materials from biowaste, source separated organics, organic fractions of MSW, and agriculture. The digester is designed to resist operational wear and tear with a slow and continuously turning agitator, allowing for very high, dry-substance fractions. This slow mixing by the agitator keeps the substrate and microbes in contact, so the addition of fluids for dilution purposes is not required.

By minimizing digester volume and the amount of accumulated fermentation residuals, their system increases efficiency and cost effectiveness. Operational and design flexibility incorporating modular extensibility and modular design allow for the expansion of existing composting plants, and the extension of fermentation facilities, as well as the installation of completely new plants. Eisenmann offers a wide variety of combination options, either steel or concrete digesters, depending on specific requirements. The plants can process multiple types of substrate and handle a wide range of waste volumes with throughput rates starting at 5,000 metric tons.

Using this approach, Eisenmann has developed a modular anaerobic digestion system that allows for maximum flexibility for a variety of applications and can utilize a wide range of feedstocks. Before feeding the organic material to the system, the organic feed material passes through a pre-processing stage for substrate conditioning. During this stage, plastic bags and containers are opened to expose organic material, remove contaminates, and reduce particle size to make digestion easier.

The substrate feeding is an automated process that allows the digesters to operate continuously. The substrate conditioning happens as needed. The material is fed to the Main Digester that converts the feedstock into biogas and digestate. At the option of the operator, the digestate can be separated into a press cake (physically similar to compost) along with a nutrient rich liquid portion. Their Post Digester module stores the liquid digestate and continues to dissolve and break down residual organics in the liquid. The solids content of the useable feedstocks range from 0 to 45% with no need for dilution. This, in turn, maximizes biogas production, and there is no need for operators to enter the system to manually unload and restack. Its robust design has a high tolerance for inorganic contaminants such as plastic and papers.

In addition to the builders and operators of anaerobic digester systems, there are the thinkers and planners. HDR provides these services that give its customers the blueprints for systems that transform and reuse organic wastes in cost-effective ways that solve their environmental concerns. HDR’s related areas of expertise include: anaerobic digestion, biogas recovery and beneficial reuse, biosolids/digestate management, composting, and effluent management. Their design teams can provide technology evaluation and validation, feasibility studies, public involvement, and waste characterization assessments. They also offer financial and economic analysis using their proprietary Sustainable Return on Investment model. Deliverable services include: permitting, regulatory compliance, impact assessments, air quality, GHG assessments, and odor control and management.

Services don't end when the permit to construct is granted. HDR follows through with customized designs that maximize return on investment and post design construction management services (including field engineering, procurement, as well as construction oversight) and follow on progressive design build efforts. Once the system is built and installed, they train the operators while their startup teams commission the plant and provide any troubleshooting. Perfect examples are their plans for the Gills Onion Advanced Energy Recovery System that uses onion waste to produce power to its plant and animal feed, and the Heartland Biogas Facility that will transform industrial and commercial food waste, agriculture wastes, and other feedstock into pipeline quality gas and compost for local farms.

Heartland Biogas LLC is the largest biogas facility in North America. The system will use a mixture of cow manure from local dairies and organic waste from restaurant grease traps, spoiled grocery store products, cafeteria waste, and food processing residuals. The facility will produce over 50 MW renewable natural gas (RNG). After the biogas is cleaned and compressed, it's injected into the Colorado Interstate Gas Company pipeline.

Gills Onions (Oxnard, CA) has a $9.5 million advanced energy recovery system, and is the largest onion processor in the country. To meet their need to efficiently dispose of plant waste, HDR Engineering Inc. developed a sustainable facility capable of reusing waste and producing power. Each day, the plant's 200,000 pounds of onion peels are ground, dewatered, and pressed to produce 30,000 gallons of onion juice and 20 tons of onion cake. The juice is digested in a high-rate up flow anaerobic sludge blanket reactor to produce biogas that powers two 300-kW fuel cells. The cake is hauled to farms for use as animal feed.

Cornerstone Environmental Group and parent company, Tetra Tech, are leaders in anaerobic digester project planning, with an emphasis on the economics of these systems. Their economic model factors in the cost of (or income from) the feedstocks, the sale of the energy produced, the sale of residual solids, and environmental credits that produce economic value. To maximize returns, project developers seek alternative uses for biogas produced. One of the options is to convert biogas into a salable gas known as RNG. This can be fed into the existing natural gas distribution system or used as a substitute for CNG as vehicle fuel.

A good example of an RNG project is their Clean World Partners' Sacramento South Area Transfer Station's Organic Waste Recycling Center, in which Atlas Disposal trucks bring material to a food waste digester, then fill up their trucks with BioCNG vehicle fuel. Another example is the South San Francisco Scavenger Company's (SSFSC's) Blueline Transfer Station, which will use biogas from food and green waste to fuel SSFSC's fleet of collection trucks.

Tetra Tech offers complete bioenergy services, including the development, design, construction, operation, and maintenance of the facilities to ensure efficiency and regulatory compliance. They have performed more than $500M in design-build and engineer-procure-construct, and implemented more than 200 of these projects. They conduct assessments and technology implementations best suited to their clients' goals and situations with follow-up turnkey services, including planning, development, design, build, operation, and maintenance services.

In the field of anaerobic digestion, Tetra Tech has completed over 100 anaerobic digester projects, including lagoon, complete mix, plug flow, and high solid digesters. These projects utilize numerous types of feedstock and cosubstrates, including MSW; livestock manure (dairy and poultry); food waste such as fats, oils, and grease; bakery waste; brewery waste; and other waste products. Their specialty expertise consists of: MSW conversion via numerous high solids anaerobic digestion technologies (including the successful completion of the design), construction management, as well as the commissioning of one of the first digester facilities to inject and sell utility grade biomethane to a public utility.

Since the market for new waste conversion technologies was revived around 2005, SCS Engineers has assisted clients with evaluating the veracity of these technologies. SCS has focused on evaluating the technical and economic viability of technologies. The technologies include thermal, biological, and biochemical hybrid processes.

SCS has developed an in-house team of professionals with specific experience in this niche market and capability to respond to inquiries across the US from clients that include municipal agencies, lenders, private waste companies, equipment vendors, etc. SCS has completed some 30+ technical and economic assessments in the waste conversion market, including specialized assignments such as economic/pro-forma assessments, feasibility studies, byproduct market studies, troubleshoot existing facilities, environmental impact assessment, energy balances of operating facilities, plant siting studies, environmental permitting, supporting engineering services, and grant application assistance.