BioCycle energy

EUROPEAN TRENDS

ANAEROBIC DIGESTION OUTLOOK FOR MSW STREAMS

With successful operating experience in the 20,000 tons/year capacity range, more cities and project developers are moving forward with large-scale AD projects.

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ENERGY produced from digester biogas is categorized as "green energy." The processing of a range of waste streams, including source separated organic waste or mixed municipal waste in anaerobic digesters (AD) contributes to sustainable and renewable energy targets set by cities, electrical utilities and state governments across North America and Europe. Given that many jurisdictions have set mandatory RPS (renewable portfolio standards), AD projects are becoming increasingly attractive as one of a portfolio of green energy sources that can contribute to the goal.

In a world where carbon trading and carbon neutral are the current buzz words, anaerobic digestion is looking like an exciting new prospect to many stakeholders. This article reviews developments in AD systems and projects, focusing on trends in European countries. A brief description of anaerobic digestion basics assists in understanding distinctions between the AD approaches.

ANAEROBIC DIGESTION 101

Anaerobic digestion occurs in two phases: In the first phase a group of microorganisms referred to as "acid formers" breaks down complex materials in an acidic environment. In the second phase, a second group of microorganisms referred to as "methane formers" breaks down the output from the first phase and consume the organic material to form biogas.

Anaerobic digester equipment is sold by a number of vendors who vary the following process parameters: Retention time in the digesters (which varies from 10 to 25 days generally); Moisture content in the digesters (dry vs. wet designs); Operating temperature (two operating regimes, thermophilic or mesophilic are used); and Number of stages (one or two).

There are trade-offs between each of these parameters and the final decision depends on local conditions and project objectives. A few key trade offs are worth noting:

Wet vs Dry: Wet digestion operates at a higher moisture content than dry digestion. Moisture is added to the incoming waste stream, which is preprocessed by a number of different technologies. The higher moisture content of wet digestion is an advantage for programs with a lot of plastic, as the plastic can be floated off before digestion. Wet preprocessing has also proven successful in Toronto where separation of material such as fine particles of glass (which would compromise the quality of finished compost) is needed.

Wet digestion typically results in a loss of volatile solids from the incoming waste stream, and this can lead to lower gas yields. Wet digestion also uses more of the energy generated from biogas (up to 50 percent) for higher in-plant energy needs (pumping, dewatering) than dry digestion technologies (20 to 30 percent of energy is typically required for in-plant needs).

Mesophilic vs. Thermophilic: Mesophilic digesters operate at a lower temperature, and therefore retention time is longer (15 to 30 days) to generate the same level of organic breakdown. Gas production is reported to be lower in mesophilic digesters, although the biological process is considered more stable. The longer retention time results in more space requirements and higher costs. Thermophilic digestion has a reported higher gas yield and a shorter retention time (12 to 14 days), lower space and tankage requirements, but higher maintenance requirements and costs.

One Stage vs. Two Stage: Some manufacturers design their AD systems for both the first and second phases to occur in one tank. Others split the phases into two tanks in order to optimize operating conditions for each. Single stage digestion is a simple design with a longer track record, and has lower capital costs and technical problems. Two stage systems have lower retention times as each stage design is optimized. There is a potentially higher gas yield with two stage systems, but higher capital costs.

Biogas from digesters is 55 to 60 percent methane; the remainder is mostly CO_2. The biogas typically is used to generate heat or steam, through combustion in boilers, or it is used to generate electricity. Some AD facilities convert the biogas to fuel for the company fleet.

Biogas generation varies by material. There is limited information on the comparative biogas generation of different materials in source separated organics or mixed waste streams. AD designers generally use

Table 1. Competitive biogas yield from different MSW materials (Barlaz[1])

Material	Moisture (% wt)	Biogas Yield m³/kg Of Material Feed*[2]	Biogas Yield ft³/lb Of Material Feed
Paper			
Newspaper	10	0.061	0.98
Cardboard/boxboard	10	0.125	1.89
Telephone directories	10	0.061	0.98
Office paper	10	0.178	2.85
Mixed paper	10	0.112	1.80
Kitchen Waste			
Food	70	0.113	1.82
Yard waste			
Grass	60	0.034	0.55
Leaves	60	0.023	0.37
Brush	40	0.067	1.08
Other organic		0.101	1.62

Sources: ICF, 2005 and Hackett & Williams, 2004. [1]Barlatz, (1997). Biodegradative Analysis of Municipal Solid Waste Components in Laboratory Scale Landfills. M.A Barlaz, EPA 600/R-97-071.1997; [2]Gas production values assume a methane yield of 0.22 m³/kg (3.52 ft³/lb) of VSS (Volatile Suspended Solids).

their own proprietary data. Research was carried out by Dr. Morton Barlaz of North Carolina State University to model the relative breakdown of different materials in a landfill, which is an anaerobic environment (Table 1). The table shows that the comparative gas yield (from most to least) is: Office paper, mixed paper, cardboard and boxboard; Food; Telephone directories and newspaper; Brush; Grass; Leaves. Table 2 shows reported biogas yields from different MSW feedstocks in anaerobic digestion facilities in Europe.

The Dufferin Organics Processing Facility in the City of Toronto, Ontario reports a biogas production rate of 159 m³/metric ton (5,600 cu ft/ton), whereas some European vendors quote rates of 85 m³/metric ton (3,000 cu ft/ton) for single stage digestion systems and 95 m³/tonne (3,350 cu ft/ton) for two stage systems.

ANAEROBIC DIGESTION OF SOLID WASTE IN EUROPE

Anaerobic digestion has been used to stabilize biosolids in wastewater treatment plants for almost 100 years. Wastewater treatment plant engineers and designers are familiar with the process dynamics and the design concepts are well understood. However, wastewater treatment biosolids are a relatively homogeneous waste material. It is more challenging to design a digester to handle the somewhat heterogeneous and seasonal nature of source separated organics and other solid waste streams, but there have been significant developments in the area in the last 15 years. During that same time period, interest in anaerobic digestion of solid waste has been growing steadily in Europe.

Part of that interest is attributed to the European Union Landfill Directive that requires EU member states to stabilize organic material prior to landfilling, and to meet the following stabilization targets (expressed as the amount of unstabilized waste that can be landfilled): 75 percent of 1995 level by 2006; 50 percent of 1995 level by 2010; and 35 percent of 1995 level by 2016. Waste can be stabilized by incineration (with energy recovery), composting or digestion.

Because of the EU Landfill Directive, there has been a flurry of activity in Europe, with municipalities constructing various stabilization plants, including digesters, composters and MBT (mechanical biological treatment) plants that use either digestion or composting for the biological component. Anaerobic digestion processing facilities can afford to charge high tip fees (up to $140/metric ton) in European countries subject to the Landfill Directive as they are competing with incineration and landfilling, both of which cost $90 to $140/metric ton (MT). There are green power incentives in many European locations, where all green power produced by digesters must be purchased by the local utility for a minimum of 15 cents/kwhr. The combination of high tipping fees and high energy revenues makes the economics of digestion attractive in many European locations.

Processing of the organic portion of MSW alone (as biowaste) is a very common practice in Europe to meet the EU Landfill Directive. In addition, many communities codigest MSW with animal manures or biosolids

Table 2. Comparative biogas yields from different AD facility MSW feedstocks

Input Digestion	Nm^3CH_4/raw Ton	Biogas (m^3/t)	Biogas (ft^3/t)
Food waste + garden waste	50-60	80-90	2,800-3,200
Food waste + low level of cardboard	65-75	104-112	3,700-4,000
Food waste + cardboard + garden waste	65-75	104-112	2,700-4,000
Food waste + cardboard	75-85	112-136	4,000-4,800
MSW	75-90	112-144	4,000-5,100

from wastewater treatment facilities.

The municipal solid waste AD market in Europe has grown exponentially over the past five to 10 years. It was estimated that in 1999, European AD plants processed about one million tons/year of mixed MSW or source separated organics (SSO) in 53 plants. In 2005, it was estimated that there were 74 AD facilities in operation, mostly in Europe, processing SSO or mixed MSW. In 2006, it was estimated that the number of AD facilities commercially operating or under construction had increased to 124 (many of the facilities under construction in 2005 had become operational in 2006), processing almost 4 million tons/year of waste. Table 3 shows the number of anaerobic digestion facilities managing MSW in European Countries in 2006.

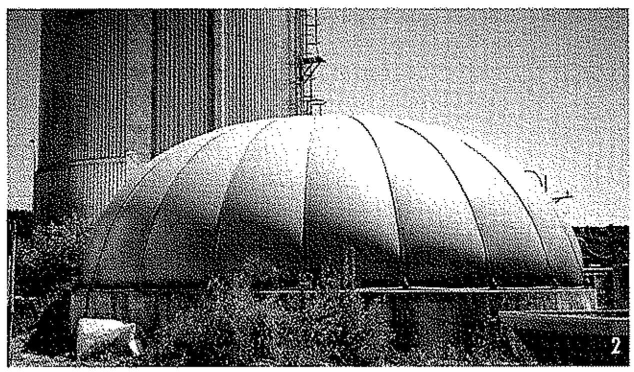
Many of the AD facilities currently in operation, particularly those with operational experience of greater than five years, have capacities smaller than 20,000 MT/year, although there is a trend to build larger anaerobic digestion facilities because of economies of scale.

ANAEROBIC DIGESTER VENDORS

There are 15 anaerobic digestion technology vendors of significance in the global market at this time, with a number of facilities in operation. The majority of the AD vendors are based in Europe, with seven providing about 70 percent of the AD capacity in Europe and 80 percent of the facilities. Some companies involved include: Kompogas (Swiss); Dranco (Belgian); Linde (German); Biopercolat (German); ISKA (German); Valorga (French); APS (US); Bioconverter (US); Arrowbio (Israel); BTA (German); Waasa (Finland); Linde (German); Entec (Austria) RosRoca (German); and Hasse.

Some of the key European vendors (five of the top seven) have established North American partnerships, and a number have been making significant efforts to penetrate the North American market (in particular Dranco, Valorga, Arrowbio, BTA and Kompogas). There are several U.S. anaerobic digestion companies now in business. Table 4 profiles the key AD companies with partnerships in North America.

A newer trend in Europe is to market anaerobic digestion as one component of an integrated MBT system. Traditional AD vendors have begun to partner with larger MSW processors who already have composting technologies or facilities, as well as transfer stations and/or landfills. These trends are expected to continue with the increased interest in renewable energy and waste diversion, as well as organic stabilization targets in the EU Landfill Directive. The advantage of MBT for many communities is that organics do not have to be source separated by residents. Some AD vendors are happy with a paper-rich feedstream, as gas production is higher.



Food waste is delivered (1) to a Kompogas anaerobic digestion plant near Zurich, Switzerland. A gas storage unit (2) is in the foreground of a Swiss digester facility. Some plants in Europe convert biogas to fuel for fleet vehicles (3).

In addition to AD plants in Europe to process source separated organics and mixed waste there are a few in Japan and other countries. There are also many digester facilities that operated for a short period and were closed, and each new generation of digester designs learns from the earlier failures.

Spain reportedly sends the most waste to anaerobic digestion of all the EU countries. This has been precipitated in part by a directive by the Spanish parliament in August 2005 to increase renewable energy production from 19 percent of the total energy mix to 31 percent. The increased goal applied to both thermal and digestion facilities.

Spain reports having 23 operating AD facilities processing about 1.8 million MT/year and producing over 500,000 MWhrs/year. Some of this capacity is provided by 12 wet digestion facilities (6 Ros Roca, 4 Linde, 1 BTA and 1 Haase) and seven dry facilities (3 Valorga, 2 Dranco, 1 Linde and 1 Kompogas) located all over the country. Ecopark in Barcelona has a few different AD technologies in operation, including a 90,000 MT/year facility constructed by Ros Roca.

ANAEROBIC DIGESTION IN NORTH AMERICA

There are two full-scale AD facilities currently operating in North America that process MSW, both near Toronto, Ontario, Canada. The City of Toronto's Dufferin Organics Processing Facility has been operating full scale at a capacity of 25,000 MT/year since 2004 using BTA wet digestion technology. It is located at the city's

Table 3. European countries with facilities processing MSW in anaerobic digesters in 2006[1]

	Number Of Plants	Approx. Total Country Capacity (tpy)
Germany	55	1,250,000
Spain	23	1,800,000
Switzerland	13	130,000
France	6	400,000
Netherlands	5	300,000
Belgium	5	200,000
Italy	5	160,000
Austria	4	70,000
Sweden	3	35,000
Portugal	3	100,000
United Kingdom	2	100,000
Denmark	2	40,000
Poland	1	20,000
Total	128	

[1]Mata-Alvarez, Joan April 2006; DRANCO information and Spanish data from "Status And Trends of the Residual Waste Treatment Options (Landfilling, Mechanical-Biological Treatment and Incineration) in Spain, Dr-Ing., Dieter Jurgen Korz presented at Conference on "The Future of Residual Waste Management in Europe" 2005.

Table 4. Companies processing MSW in anaerobic digesters in Europe in 2006[1]

Company	Technology	Number Of Plants Internationally	Approx. Total Capacity (tpy)
Valgora International, France	Valgora	15 (Europe)	1,000,000
OWS, Belgium	Dranco	16 (Europe), 1 (Korea)	475,000
Kompogas, Switzerland	Kompogas	23 (Europe), 1 (Japan)	500,000
BTA, Germany	BTA	10 (Europe), 1 (Canada), 1(Korea)	350,000
Arrow Ecology, Israel	Arrowbio	1 (Israel)	52,000

[1]Various sources including, Kelleher Environmental in-house data, Mata-Alvarez, Joan April 2006 and DRANCO information

Dufferin Transfer Station. The city's Green Bin program provides curbside household organics collection to 500,000 households and 20,000 businesses, therefore a large source separated organics stream is available for processing at the facility. (See "Evaluating AD System Performance For MSW Organics," November 2006 and "Managing AD System Logistics For MSW Organics," December 2006.) The second facility, located in Newmarket, Ontario outside of Toronto, also uses the BTA wet digestion technology. The plant, owned by Halton Recycling, had been closed but recently restarted at a lower throughput than its design capacity of 400 MT/day (see "Source Separated Organics As Feedstocks For Digesters," August 2005).

Until very recently, there were no anaerobic digestion facilities operating in the United States that processed MSW or source separated organic waste. In October 2006, Onsite Power Systems Inc., in association with the University of California Davis, launched their biogas energy project with the start-up of an anaerobic digester. This AD facility will initially process residential and restaurant waste from San Francisco, gradually increasing the amount to eight tons/day. Each ton of food waste is expected to generate enough bioenergy to power and heat 10 homes over a 24-hour period.

A number of large communities in the United States have undertaken feasibility studies evaluating anaerobic digestion as part of "New and Emerging Technologies" or "Conversion Technologies" to treat municipal waste. One of the attractions of AD in particular is the ability for cities to use AD to reach renewable energy targets. A report issued by New York City on New and Emerging Technologies for MSW found that anaerobic digestion and thermal (gasification) technologies were less costly on a commercial scale than the current waste export practices. The analysis concluded that AD offered better environmental performance than waste to energy facilities, with lower air pollutant emissions, increased beneficial use of waste and reduced reliance on landfilling. A number of other U.S. communities, including Los Angeles, Seattle, Santa Barbara County and Alameda, have examined AD technologies as part of these evaluation processes.

FACILITY SCALE, COSTS

Until about five years ago, many AD plants were relatively small (< 20,000 MT/year). At this size, there is plenty of successful operating experience. The trend now is towards larger AD facilities. One key question is the extent to which the successful operating experience at <20,000 MT/year is scalable to larger capacities.

A number of facilities are on the drawing board, or have been constructed recently to process 100,000 MT/year or more. However, there has been limited operating experience with AD facilities with a capacity larger than 50,000 MT/year.

There is very limited information available on the costs of existing AD facilities, mostly located in Europe. European vendors can provide general ballpark costs of constructed facilities, but it is hard to translate these to a North American setting.

Cost information is available for the Dufferin Organics Processing Facility in Toronto. Operating costs (excluding the cost of amortized capital) for that facility are estimated at about $139/MT of input, consisting of $112/MT paid to the operator plus $27/input MT paid by the City for hydro and residue disposal. Amortized capital is re-

Table 5. Estimated costs of anaerobic digestion facilities to process source separated organics (SSO) and mixed waste

	Population							
	20,000		80,000		200,000		800,000	
	SSO	Mixed	SSO	Mixed	SSO	Mixed	SSO	Mixed
Annual input quantity to facility (metric tpy)	2,000	2,470	7,500	10,000	18,500	24,700	100,000	100,000
Cost per input metric ton ($/year)	$257	$282	$156	$172	$111	$123	$68	$68

portedly an additional \$50/input MT for a total cost of about \$190/input MT.

However, as with most AD plants, it is hard to compare the Dufferin Organics Processing Facility costs with other plants because it is an "apples to oranges" comparison. The Dufferin facility was located within an existing City of Toronto transfer station site, and therefore saved some costs that would be incurred if an anaerobic digester was constructed on a greenfield site (i.e. a site which has to be developed specifically for the digester, with no other infrastructure in place).

Estimates were developed in a recent Government of Canada study for digestion of both SSO and mixed waste for communities with populations of 20,000, 80,000 and 200,000. Findings shown in Table 5 are based on the following assumptions: Biogas production of 110 m^3/MT for SSO and 130m^3/MT for mixed waste (because of increased amounts of fine paper); Composting of digestate at \$25/MT; No revenue from heat sales; Revenue of 6 cents/kWhr for green, renewable power (based on similar prices paid on Prince Edward Island at this time); and Disposal of residue at \$30/MT.

The quality of the finished digestate, which is ultimately converted to compost, is more of a challenge for MSW (mixed waste) digestion, as there is more contamination in the incoming feedstream which needs to be removed to produce a finished compost of acceptable quality (aesthetic as well as chemical).

THE FUTURE OF AD

There are a number of environmental benefits to using anaerobic digestion to stabilize either a source separated organics or a mixed waste stream. These include production of green energy supplanting the use of fossil fuels for electricity and heat generation; ability to make a useful product out of an organic waste stream (digestate) that can be stabilized further to produce compost; and a very small footprint.

AD will continue to develop in Europe and elsewhere where the economics of the waste management and energy markets provide the right incentives. There is increasing interest in AD in the U.S. and Canada, as green energy and energy from biomass get more attention, and cities pursue source separation of organics. Codigestion with animal manures or with municipal biosolids may make sense for some communities. Anaerobic digestion is expensive in North America compared to other waste management options at this time, but an increasing interest in sustainability, energy self-sufficiency and renewable/green energy targets are likely to create both a policy climate and guaranteed high green energy revenues that together will be favorable to AD in the longer term. ■

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MECHANIZING TIMBER HARVESTS

TURNING LIMBS AND CHIPS INTO ENERGY BIOMASS, HUMUS

Materials are loaded onto the feed tray (end of unit on left) of the bundler unit. Feed rollers pull material into the presses (toward middle of unit).

Biomass is converted to bundles as part of strategy to economically recover logging residues.

WHILE lumber and pulp mills have been using forest residuals to produce power, most of the leftover remains have been underutilized in the United States. An estimated 67.1 million dry tons of logging residues are generated annually, but the main challenge is a lack of cost-effective recovery techniques. Composed of limbs, twigs, foliage and nonsalable timber, these residues represent a substantial amount of available biomass.

Logging residue lacks uniformity and has a significantly lower density thansolid wood thereby decreasing productivity of its recovery. One of the most common methods of residuals recovery is comminution (pulverize). After materials are brought to a central point, they are ground/chopped and transported to generation facilities. Comminution minimizes transportation problems — turning limbs and tops into more easily transportable chips.

But the primary problem is poor storage ability. High surface area and nutrient content lead to rapid decomposition and dry matter loss. To become a suitable energy source, forest residuals need to be available for power generation all year regardless of weather conditions. Therefore, the storage capacity of comminuted materials is currently limited. An alternative process for utilizing forest residue is bundling. Packaging coarser pieces of debris into bundles can reduce dry matter storage loss.

One machine designed to collect forest biomass is the John Deere 1490D slash bundler. Developed to work in conjunction with cut to length machines, this unit collects forest debris, compresses material, and binds it into six to ten feet long bundles that are two feet in diameter. Several studies have investigated performance of the slash bundler in gathering forest residue from harvested sites, but so far none have looked at Deep South conditions. With the South providing about 60 percent of U.S. timber products (i.e., logging residues, timberland clearing, etc.) it's important to evaluate productivity in southern timberlands.

The bundler demonstrated its operational effectiveness in southeastern Arkansas on loblolly pine stands last July using the ratio-delay method. Ratio delay analyzes machine operations to figure the ratio between delay time and actual productivity. Materials are loaded onto the feed tray, and feed rollers begin intake of the materials into the presses, which reduce volume by about 80 percent. A three minute time frame was used, enabling the observer to monitor different activities — recording what was being done. Bundling activities included: gather, load, bundling, cut/unload, and downtime. Total number of each activity were divided by total observations at the site and then multiplied by 100 to yield the percent of time that the machine spent on a given activity. Overall, the machine was involved in productive work 68 percent of the time. Gathering and loading accounted for the highest proportion of productive work. ■

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