Biogas-fuelled microturbines already occupy a profitable niche for distributed generation in the US, particularly at small landfill sites and wastewater treatment plants. Here Christine Hurley looks at technology considerations, operating experience, and at market and site conditions, predicting continued growth for the technology.

Biogas-fuelled microturbines

a positive outlook for growth in the US

Microturbines are demonstrating some unique attributes for running on biogas that enable them to compete against reciprocating engines – particularly at smaller sites. In fact, biogas applications are among the most promising early applications for microturbines.

Biogas is available from landfill sites, wastewater treatment plants, agricultural and livestock operations, food processing plants, gasified woody biomass, or other sources of organic waste. The combustible portion of the gas is methane (CH_4). Most of the rest is CO_2, with small amounts of nitrogen, oxygen, hydrogen, water (the biggest source of problems in biogas applications), hydrogen sulphide and trace elements. Microturbine manufacturers have taken note of the market opportunities available from biogas and have modified their systems to better handle the unique qualities of biogas and the impurities it contains – see Table 1.

LESSONS LEARNED FROM END-USERS

We have interviewed plant operators at nine wastewater treatment plants and two landfill sites operating a combined total of 60 microturbines, and found the following results in common:

- Site operators are generally happy with the microturbines and would recommend them to other landfill sites and wastewater treatment plants – particularly for smaller sites.
- Early landfill and digester installations had some start-up problems, including gas compressor failures, but those problems have been resolved for existing and new sites. End-users now report few problems with the operation of biogas-fuelled microturbines.
- New Capstone installations have a standardized gas-processing system that is simpler, more compact, and more reliable than previous installations.
- Compared with their previous electricity and heating bills, operators of landfill and digester sites are reporting quite significant cost savings as a result of using microturbines – particularly where state, local, and utility grants are available to help cover the capital costs of the equipment.
- Operators of several wastewater treatment plants and landfill sites said they specifically bought microturbines because the units run cleaner than engines.

On the last point, Capstone certifies that NOx emissions will be less than 9 parts per million (ppm), but its landfill and digester applications often only have 1–3 ppm. In contrast, emissions from uncontrolled reciprocating engines running on biogas can be in the range of 50–200 ppm.

ADVANTAGES FOR BIOGAS APPLICATIONS

For many small digester and landfill sites, microturbines can provide a better solution than the alternatives, which include doing nothing, flaring off the waste gas, using it directly in a boiler, or running it through a reciprocating engine. Of course, many factors determine whether on-site generation is

Table 1. Microturbine manufacturers with biogas models. The vast majority of biogas-fuelled microturbines are installed in the US and Canada, with a handful of units in Europe, Japan and elsewhere

Manufacturer	Model name	Model capacity (kW)	Status	Number of units running on biogas
Capstone	C30 Biogas	30 [a]	Commercial	215
Ingersoll Rand	EcoWorks	70 and 250	Commercial	10
ETTI [b]	Turbo Charger Gas Turbine (TCGT)	100	Prototype	1
FlexEnergy	Flex-Microturbine	30	Prototype	1

Source: Platts; data from manufacturers

[a] Capstone is also developing a 60 kW biogas model

[b] ETTI=Energy Technology Transition Inc.

appropriate for a site – and if so, which technology to use. Reciprocating engines are well established in this market and will probably continue to be the technology of choice for many landfill and digester project developers. But there is a growing level of interest around microturbines due to their ability to use low calorific value fuel, their low maintenance requirements, low NOx emissions, modularity and portability.

Compared to other possible applications for microturbines, biogas is a good fit because the fuel is free or cheap, improving the 'spark spread'. The only fuel costs are for the collection and pretreatment of the waste gas. Collection costs at many landfill sites and wastewater treatment plants are often insignificant, because, as Ron Meyer, Engineering Associate at the Santa Margarita Water District, California, puts it, 'We would have to do something with it anyway'. Also, grants and incentives for biogas projects are available from multiple sources, improving the economics.

Between grants defraying some of the capital costs and the fuel being a by-product of the treatment process, wastewater treatment plants and landfill sites have shown some attractive economics for microturbine projects. According to our interviews, the Town of Lewiston Water Pollution Control Center, New York, is netting US$36,000 in annual savings, San Elijo Water Reclamation Facility, California, is saving about $48,000 annually, Eastern Municipal Water District, California, has $57,000–63,000 in electricity cost savings per year, the City of Allentown Wastewater Treatment Plant, Pennsylvania, is saving $25,000 per year for 10 years and $150,000 annually thereafter, and the Daly City Department of Water and Wastewater Resources, California, estimates $216,000 in savings per year.

LANDFILL SITES

Landfill gas-to-energy projects in the US have an average installed capacity of 3.5 MW. Microturbines have been installed in so-called 'multipacks' of 10, 12 or even 50 units at landfill sites, but average landfill gas-to-energy projects are generally too big to be appropriate for microturbines. Yet, with many of the larger landfill sites already developed, some landfill gas specialists are successfully turning their attention to the hundreds of undeveloped smaller landfill sites – where microturbines do have a niche.

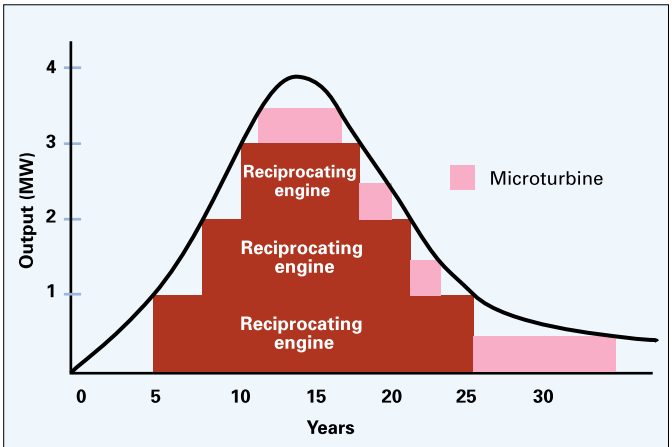

Figure 1. Landfill gas production peaks, then falls off over time. Microturbines can help to fill in the gaps around larger reciprocating engines, to get the most out of the gas supply

Two views of the microturbine installation at the San Elijo Water Reclamation Facility

Some developers are also siting microturbines at older landfill sites, where the methane production has already peaked and is falling off (see Figure 1). An example from Europe is Verdesis, a company in which Electricité de France has invested, which is developing old, closed landfills in several European countries using microturbines – often at sites that previously had a larger reciprocating engine. Bertrand Courcelle, a partner in the company, says Verdesis likes to use microturbines at these sites because engines adapted for landfill gas with capacities less than a few hundred kilowatts are harder to find. Courcelle also mentioned that microturbines are easier to move from site to site so that power generation can follow the landfill gas production curve.

Besides smaller landfill sites and old, closed sites, microturbines are also appropriate at landfill sites in drier climates where the methane content is lower. (Organic matter decays more slowly in drier climates.) Microturbines can tolerate a methane content down to 30% or less, whereas many small reciprocating engines struggle with a methane content less than 40%. Reciprocating engines can require 'sweetening' with purchased natural gas or propane when the methane content is too low.

Over 100 microturbines are currently running on landfill gas in the US. Most of the electricity generated is exported to the grid or to a nearby load, since landfill sites tend to have small on-site loads. A site with a methane collection system already in place will certainly look more attractive for an electricity generation project than one without. Larger landfill sites in the US are required by law to have a methane collection system in place for safety reasons, but many smaller sites are not subject to the same law.

Landfill sites that have a use for the waste heat from the microturbines are also more attractive – yet most sites don't have a use for the heat.

One creative example is a landfill site near Antioch, Illinois, which is piping landfill gas over to 12 Capstone microturbines at a high school (about 1 km away). Recovered heat is used for the school's sports complex and swimming pool. This illustrates another point: using the biogas to supply on-site or nearby loads, rather than exporting all the electricity to the grid, means that price can be compared to retail electricity prices rather than wholesale prices.

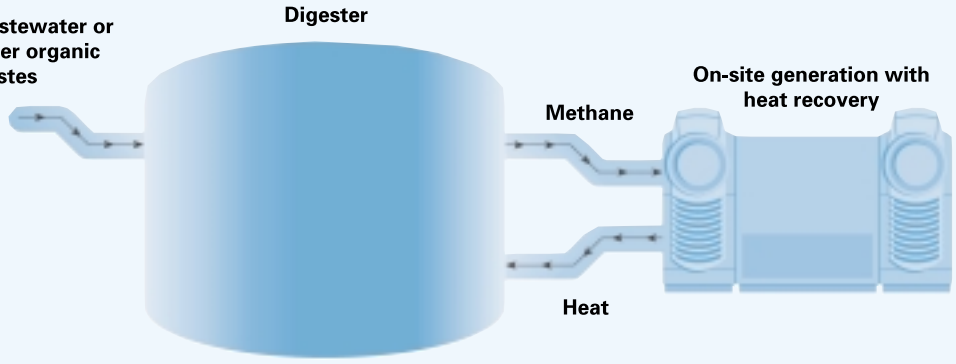

Figure 2. For wastewater treatment plants or other sites with anaerobic digesters, the waste heat from cogeneration is at least as equally useful as the electricity. Waste heat is used to help heat the digester and maintain the process temperature of about 38°C. Wastewater treatment plants will use any extra heat to warm the 'people spaces' of the control building

WASTEWATER TREATMENT PLANTS

Wastewater treatment plants are an excellent application for microturbines because they can feed the microturbines' waste heat back into the digester to maintain the process temperature. Typically, these plants will use the microturbine waste heat to preheat water for their boiler, thus saving on natural gas costs – see Figure 2. Ron Meyer at the Santa Margarita Water District, which has two 30 kW Capstone microturbines with heat recovery, commented that 'the plant operators are really excited about the project – the efficiencies, the heat production, and the savings. They're actually more interested in the heat than in the electrical production, because they use it day-to-day. And they have a couple of ideas for even more ways they can use the heat.'

Even though nearly every region of the US has a wastewater treatment plant, only plants that use anaerobic digestion as part

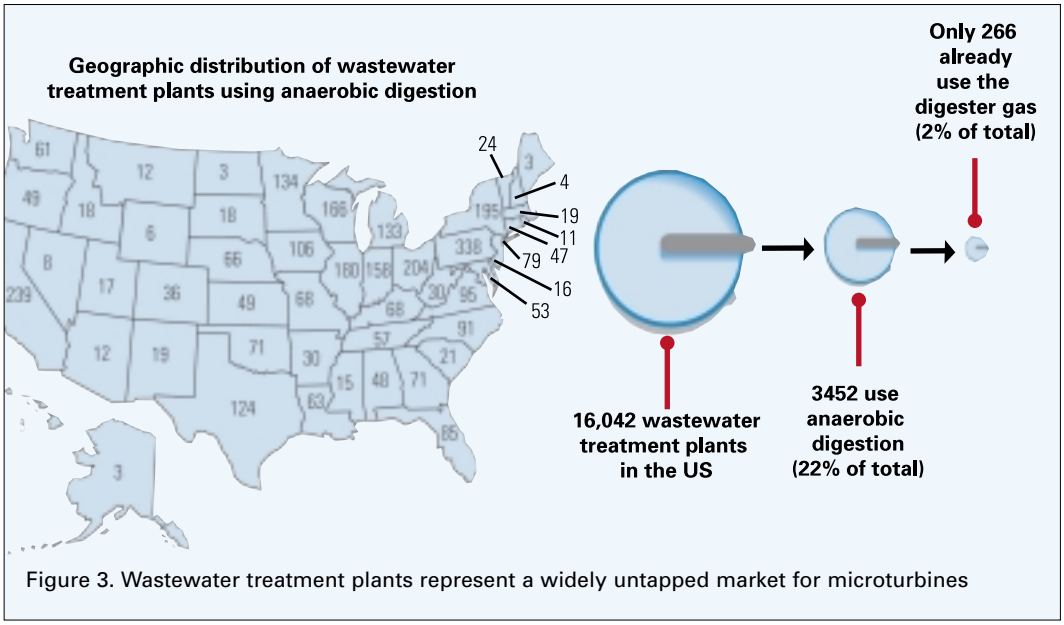

Figure 3. Wastewater treatment plants represent a widely untapped market for microturbines

of their treatment process produce biogas. Most of the plants that do have anaerobic digestion, though, often just flare off the biogas, because plant operators are focused on meeting water quality and disposal standards rather than energy production. Consequently, these plants represent a largely untapped market – see Figure 3.

The size of wastewater treatment plants varies. Some plants barely produce enough digester gas to power a single small microturbine. For example, the Jeannette wastewater treatment plant, east of Pittsburgh, only has enough biogas to operate its 30 kW-rated Capstone microturbines at 18 kW. The largest wastewater treatment plants produce enough biogas for 20–25 MW. As with landfill sites, microturbines are really more suitable at smaller plants than larger ones. The Town of Lewiston Water Pollution Control Center, for instance, has two Capstone microturbines. Timothy Lockhart, Chief Operator, says, 'We're a 2.75 million gallon (per day) plant. If you're in that neighbourhood, it's a pretty good application for microturbines. If you're a larger facility, you're probably better off running one large reciprocating engine rather than 15 or 20 microturbines. But for a smaller niche, I think it's a good fit'. Ingersoll Rand's new 250 kW EcoWorks microturbine will expand the range of landfill and digester sites appropriate for microturbines.

In total, about 100 microturbines currently run on biogas from wastewater treatment plants in the US. Most plants use all the electricity output from the microturbines, and don't export to the grid.

Besides having a good use for the waste heat, wastewater treatment plants have some other specific advantages for microturbine applications. Compared to other market sectors, municipal-owned wastewater treatment plants have access to capital, can tolerate a longer payback period, and are already somewhat familiar with distributed generation, since many have back-up generators. On the other hand, some installers anecdotally report that water agencies can be bureaucratic to work with (so the sales cycle is longer), and that, as a sector, wastewater treatment plants are generally reluctant to try new or unfamiliar technologies.

AGRICULTURAL AND LIVESTOCK OPERATIONS

With only minor modifications, microturbines can be run on waste methane from digesters at dairy, hog (pig) and poultry farm operations as easily as at wastewater treatment plants. The driver for farm operators is to manage wastes – especially manure. In addition to providing a treatment route for manure, with fertilizer as an end product, digestion eliminates odour problems that arise from storing manure in a lagoon, and prevents groundwater pollution.

The resource is enormous, the application is technically feasible and proven, and the environmental and community benefits are huge. However, the outlook for this application is mixed. In the US, there is currently a lack of financial assistance to farm operators for developing projects ('carrots'), and a lack of regulations mandating stricter animal waste management ('sticks'). Both of these are slowly starting to shift.

The US currently has 35 farm-scale anaerobic digestion projects in operation, generating about 4 MW. This is a 30% increase from two years ago, and another seven projects are in start-up or under construction. Most of these existing and new projects use reciprocating engines.

Over 100 microturbines are currently running on landfill gas in the US

Compared with putting microturbines at landfills or wastewater treatment plants, the costs of projects at agricultural and livestock operations are higher, for two reasons. The waste collection system is more complicated, and farm operators are less likely to already have a collection system or a digester in place.

Organizations such as the New York State Energy Research and Development Authority (NYSERDA), the California Energy Commission, and the US Environmental Protection Agency's AGSTAR programme are helping by funding and facilitating new projects, and this will lead to an increase in biogas projects at farms. In general, though, we predict that this market will continue to consist mainly of demonstration projects rather than widespread adoption for the next several years.

Alliant Energy down on the farm

The Top Deck Holstein Dairy is one of three farms so far to have benefited from Alliant Energy's drive to support distributed generation at farms in Iowa and Wisconsin. Manure from 700 cows feeds a digester, which in turn producing gases that power a 100 kW reciprocating engine and a 30 kW microturbine. Alliant's activities in this area are driven by two issues:

- on-farm generation supports voltage levels on rural parts of their distribution network, potentially offsetting grid reinforcement costs
- Alliant wants to support a prosperous agricultural economy in its service territories in order to maintain electricity demand, and the utility sees on-farm power generation as a contributor to this.

Alliant offers to purchase gas from farmers' digesters and install, own and operate generating equipment at farms. It requires farmers to do a daily 20-minute check of their equipment, with all servicing carried out by Alliant field engineers. The company, currently running gas reciprocating engines and a Capstone microturbine, also plans to try out one of STM Power's 25 kW Stirling engines when a suitable site is identified.

Alliant has a target of 20 MW of generation on farms in Iowa and Wisconsin. After getting started in this area back in 2000, its efforts have been frustrated by the poor market conditions affecting the dairy industry. Although the company is happy to take the capital cost of the generator and switchgear off the farmers' hands, it is more reluctant to invest in the digester. The generator and switchgear are relatively recoverable assets, whereas Alliant would prefer not to tie up capital in the immovable digester. So at present, farmers have to invest in the digester which, under present market conditions, is generally a step too far for most of them. To ease the problem, Alliant is discussing possible financing arrangements with other organizations.

The slurry pump (foreground) and the cogeneration room (background) at one of Alliant Energy's farm-based digester/cogeneration projects

TECHNOLOGY CONSIDERATIONS

Biogas is a challenging gas to work with. It often requires rigorous pretreatment to filter out siloxanes, moisture content, and trace elements, which could otherwise wreak havoc on microturbines or other prime movers. With plenty of experimentation, microturbine manufacturers have developed a relatively standardized fuel skid that cleans and conditions the fuel. Capstone's fuel skid is shown in Figure 4. Finding a cost-effective gas pretreatment approach has been a major factor in the acceptance of microturbines for landfill and digester applications. The operation and maintenance costs of the pretreatment system and compressor are projected to be 1–2 cents/kWh.

Most sites will need to boost the pressure of the gas with a compressor. Capstone has found that sliding rotary vane compressors work best for biogas applications. Ingersoll Rand uses its own screw compressor.

The moisture in biogas has to be removed, or it will build up sticky deposits inside the microturbine. Capstone has found that a refrigerated dryer is better than a desiccant dryer.

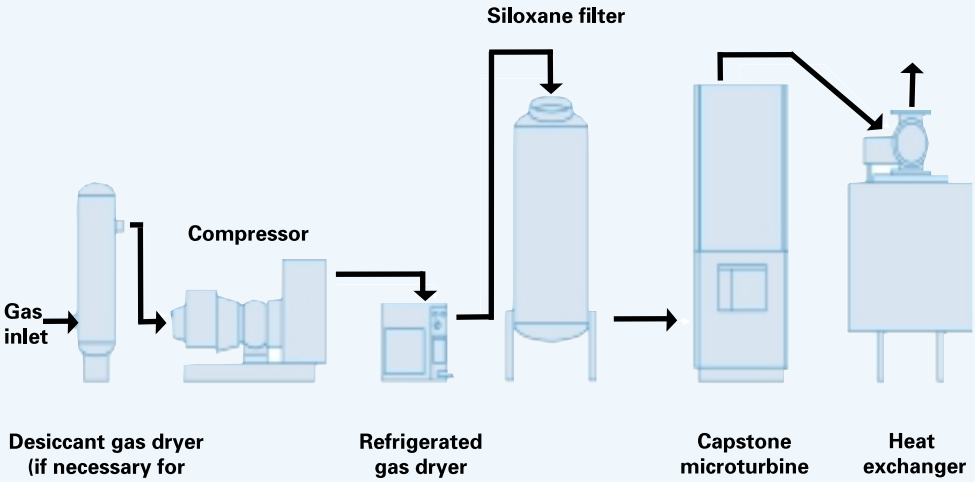

Figure 4. Capstone's new standard fuel skid for landfills and digesters. All of the company's new landfill and digester-gas installations will be set up with this standard gas cleanup system. This is simpler and more compact than previous gas cleanup systems for biogas-fuelled microturbines. Older systems used multiple compressors, multiple dryers, and a more labour-intensive siloxane filtration system. Ingersoll Rand's fuel skid is similar to Capstone's, but it is testing out combining the dryer and siloxane filter into one unit

Siloxanes – which are found in the residues of shampoos, conditioners, and cosmetics – turn into a hard, sand-like precipitate when combusted and can build up as deposits on the recuperator. It usually needs to be filtered out, using activated carbon. There is a wide range in both the first and operating costs of the siloxane filtration, depending on the siloxane concentration. First costs can range from $100–200 per kW installed. The medium in the siloxane filter needs to be changed periodically, and each change-out can be costly. The Town of Lewiston Water Pollution Control Center changes its media approximately every six months, at a cost of $900 per change-out. At the Santa Margarita Water District, replacing the media costs about $1600 per change-out, which occurs approximately every 80 operational days.

Ingersoll Rand is testing a new, super-refrigerated dryer that will eliminate moisture and siloxanes at the same time. Unlike the situation with activated carbon siloxane filtration, this new method will not require costly media change-outs. Ingersoll Rand expects that both first costs and operating costs will both be reduced.

Another difference between a biogas-fuelled microturbine and a natural gas-fuelled microturbine is that, if hydrogen sulphide is present in the gas, the exhaust heat recovery components should be made of stainless steel construction to avoid corrosion.

Microturbines require a lot of gas pretreatment at the front end, but as a result they require far less ongoing maintenance than reciprocating engines. Lower maintenance requirements have been a key selling point for microturbines. Gary Bankston, Manager of Power Production at the California water utility Inland Empire Utilities Agency, commented, 'If the staff at a wastewater treatment plant are afraid of internal combustion engines – especially regarding the maintenance work, the cost outlays, and the skill level it takes to maintain engines – then I'd say yes, go ahead and throw in some microturbines. It's easy to make some power with them, and your staff can easily learn to work with them.' Inland Empire has been testing some 20 microturbines and running several engines as well.

FUTURE DIRECTION

We believe that the market for microturbines at small landfill sites and wastewater treatment plants will continue to grow in North America. The technology design and performance, the regulatory requirements, and the financial incentives combine to give these applications a boost. However, agricultural and livestock operations, though excellent applications for microturbines, will probably consist mostly of demonstration projects in the next few years, due to the higher cost of projects and the lack of incentives for farm operators.

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