MICROTURBINE OPERATING EXPERIENCE AT LANDFILLS
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ABSTRACT
Microturbines have been sold commercially in landfill and other biogas applications since early 2001. The following paper will discuss the early operating experiences using Capstone MicroTurbines in landfill gas projects, culminating in the technical and economic issues related to the successful development of the most recent 300 kW Capstone installation at Calabasas Landfill in Southern California.

INTRODUCTION
Capstone Turbine Corporation was the first to market microturbines commercially beginning in 1998, and has since sold and shipped more than 2,400 microturbine systems worldwide. Characteristics of Capstone MicroTurbines include:

- a low emissions profile with no post-combustion exhaust devices or chemicals;
- a single moving part;
- air bearings and air cooling;
- flexibility to use a wide range of fuels, including flare gas with up to 7% H_2S;
- optimized for 24x7 full-load operation;
- ability to follow electric demand load;
- unlimited grid-connected scalability
- built-in 2-20-unit grid-independent arraying with no external hardware (up to 100 grid-independent units with one minor networking hub);
- built-in power conditioning, synchronizing and Direct2Grid™ interconnectivity functionality and safety (UL-certified to 1741 and state-certified for direct grid interconnection in CA and NY).

These characteristics enable:

- energy cost control and grid power conservation at host sites
- NOx and greenhouse gas emissions control / reduction
- minor scheduled maintenance needs (primarily filter, injector, temp. sensor and ignitor [spark plug] cleaning or replacement once every 1 to 2 years, if operated 24x7)
- no gearbox, pumps or other mechanical subsystems that introduce maintenance and reliability issues
- no lubricants, coolants, other hazardous fluids, or even water
- ability to operate on liquid fuels as well as models to use a wide Btu range of gaseous fuels (350 – 2,600 Btu/scf).

To date, microturbines have been primarily placed into service as grid interconnected stationary power generators using natural gas fuel. Variations on the technology have resulted in liquid fuel utilization, grid-independent operation, hybrid electric vehicular applications, and medium-Btu[1] flare gas utilization.

The following sections will detail the topics below:

- Early LFG Projects
- Calabasas Microturbine Project
- Newly Commissioned and Upcoming
- Conclusions & Recommendations

[1] 350 – 700 Btu/scf HHV, Capstone Engineering Specification ES-0463

EARLY LFG PROJECTS

By the summer of 2003, there will be about 100 microturbines operating on landfill gas (LFG) in the USA and abroad. Capstone Turbine Corporation's first five experiences with LFG as an exclusive fuel source took place at the following sites:

- Puente Hills Landfill, Whittier, CA
- South Side Landfill, Indianapolis, IN
- Burbank Landfill, Burbank, CA
- Lopez Canyon Landfill, Sylmar, CA
- Shepard Landfill, Calgary, Alberta (Canada)

Puente Hills Landfill

Puente Hills Landfill, operated by the Sanitation Districts of Los Angeles County, was the site of Capstone's first attempt to operate its 30-kW microturbine generator exclusively on biogas. The unit commenced operation in mid 2000 and ran for about 2,000 hours and before it was brought back to the Capstone R&D facility to examine effects of such fueling on the microturbine engine. Significant learnings from this beta deployment included:

- Importance of removing moisture from the LFG stream;
- Early experience with scroll compressor operation using saturated LFG, including new experience with pressure and flow requirements;
- Early experience with desiccant and deliquescent gas drying;
- Early experience with the need to filter out siloxanes (which impact the operation of *any* combustion device, including reciprocating engines).

South Side Landfill

This first commercial deployment of a microturbine on LFG was installed by Indianapolis Power & Light (IPL) at the South Side Landfill in Indianapolis. IPL Principal Engineer Dan Melvin said the utility's goal "was to be in the forefront on evaluating new technology," adding that IPL desires "to use economically feasible renewable energy resources as much as possible."

After 10,000 hours of generally trouble-free operation, the microturbine engine halted. Factory inspection has revealed a significant level of siloxane-related encrusting of the microturbine recuperator (an internal device that recovers some exhaust heat to boost fuel efficiency) and micro-scarring of the turbine surface. The engine is being replaced and the system should shortly be back online with more diligent siloxane removal.

Burbank Landfill

Burbank Landfill, operated by the City of Burbank, was the second LFG-fueled microturbine installation to go online. The deployment site has 10 Capstone C30s and gas conditioning equipment that was installed by EMCON/OWT. The system began operating in 2001 and drew praise from California Governor Gray Davis during the height of that state's energy crisis. Approximately 300 kW of power are generated for export to the local utility, Burbank Water & Power. The facility ran intermittently for approximately 3,000 hours but is currently down awaiting a new gas treatment system that has been redesigned according to Capstone best practices and learnings. The site is scheduled to return to operation in mid 2003.

Significant learnings from this site included:

- Use of desiccant and deliquescent drying for improved dew point suppression in LFG;
- Additional experience using scroll compressor technology for saturated LFG, partially leading to the current general recommendation to use sliding vane compressors.

Lopez Canyon Landfill

Lopez Canyon, operated by the Bureau of Sanitation of the City of Los Angeles, was the third Capstone LFG installation to go online prior to Calabasas. The site is home to the world's largest array of microturbines: 50 C30s installed by the Los Angeles Department of Water and Power with gas conditioning installed by EMCON/OWT. Approximately 1.2 MW of power can be generated for export into the local utility grid (net of about 300 kW used onsite). The facility won one of the US EPA Landfill Methane Outreach Program's "Project of the Year" awards for 2001 and was instrumental in the decision of the Financial Times to award the LADWP its Renewable Company of the Year Global Energy award.

Significant learnings from this site included:

- Early and successful experience with refrigerated gas drying instead of desiccant and deliquescent drying;
- Early and successful experience using sliding vane compressor technology with saturated LFG;
- The importance of sizing the fuel delivery system and LFG wells to provide the adequate volume of fuel needed to run the entire multipac (current gas volume supports only about 40 of the 50 microturbines deployed).

Shepard Landfill
In a CANMET-funded project, microturbine distributor Gridlink/Enerflex in Calgary, working with CH2M-Hill, created a trailer-mounted housing for a single 30 kW microturbine and all LFG processing equipment. The portable system offers web-based remote monitoring and dispatch.

The project had accumulated more than 1,000 hours as of mid-2002. Significant learnings from this site included:

- Discovery of gas flow deposits related to deliquescent drying media, refrigeration-type drying recommended;

- More frequent than anticipated manual draining of gas driers, automated condensate handling recommended;

These early experiences developed into a knowledge base of the best practices that SCS Energy incorporated in their Calabasas Landfill MicroTurbine Project.

CALABASAS MICROTURBINE PROJECT

Project Participants

- Sanitation Districts of Los Angeles County, local landfill owner & operator;
- South Coast Air Quality Management District, local air regulation & enforcement agency
- SCS Energy, turnkey LFG solution provider
- Capstone Turbine Corporation, microturbine provider.

Calabasas Landfill & LFG Collection System
The installation at Calabasas Landfill is the fourth Capstone landfill gas installation with several thousand hours of operation. The system incorporates the best practices from prior biogas experiences as well as those derived from non-LFG projects.

The Calabasas Landfill is operated by the Sanitation Districts of Los Angeles County (LACSD). LACSD is a confederation of 25 special districts serving about 5.4 million people in Los Angeles County. The Sanitation Districts' service area covers approximately 800 square miles and encompasses 78 cities and unincorporated territory within the County.

Calabasas Landfill is one of three active landfills in the Sanitation Districts, and occupies 416 acres at the border of the cities of Agoura and Calabasas, California. The landfill began disposal operations in 1961 and remains active with approximately 20 million tons of refuse in place. It currently accepts up to 2,000 tons of municipal solid waste daily. The Calabasas LFG collection and control system consists of:

- about 600 vertical extraction wells;
- more than 60,000 linear feet of horizontal trench collectors;
- more than 50,000 linear feet of above-grade PVC landfill gas collection piping;
- a flare station incorporating several enclosed flares.

Calabasas Landfill flares approximately 6,000 scfm of LFG containing 30 percent methane content.

Project Development
The South Coast Air Quality Management District gave LACSD ten Capstone C30s in February 2002 (the SCAQMD endorses the use of microturbines manufactured by Capstone Turbine and, in fact, has dedicated $8 million of its own funds to deploy Capstone MicroTurbines in its Southern California service territory).

Calabasas Landfill has a relatively large motor load at its flare station. Served by Southern California Edison, the landfill saw a major increase in its monthly power cost in June 2001 when California investor-owned utilities implemented significantly higher rates that remain in place today. SCAQMD's offer of free equipment coupled with the onsite power requirement and radical increase in its monthly utility costs motivated LACSD to proceed with a microturbine project at Calabasas.

While the availability of free generating equipment was an overriding factor in technology selection, the characteristics of the project favored microturbines over reciprocating engines and other onsite power technologies:

- the onsite power load was relatively low;
- the methane content of the landfill gas was low (conventional technologies would necessitate Btu “sweetening” with purchased natural gas or propane); and
- very low NO_x emissions were desired.

LACSD selected SCS Energy to provide turnkey installation of the microturbines. LACSD issued SCS Energy a purchase order on March 14, 2002, and the array first produced power just five months later. SCS Energy secured a California Energy Commission grant for this project in the amount of $75,000. LACSD prepared an interconnection application for the project; the application was submitted on February 15, 2002, which was approved by SCE five months later (Capstone microturbines are now state-certified to the “Rule 21” interconnection standard, which streamlines utility grid interconnection approval in California to as little as one month). LACSD applied for an air permit from SCAQMD, which issued the permit in May 2002.

Plant Description

The Calabasas microturbine power plant consists of the following major components:

GENERAL EQUIPMENT

- Ten 30 kW Capstone C30 MicroTurbines, shown in Figure 1 below;
- A 20 ft x 80 ft concrete pad;
- Switchgear and utility equipment;
- Motor control center for the motors on the compressor skid;
- SCS-designed plant control computer with touch screen interface and wireless access;
- A dedicated landfill gas collection header with designated wells;
- Piping interconnection with the flare station and condensate collection system.

SPECIFIC LFG PROCESSING EQUIPMENT

- Liquid knockout;
- A 50 hp, 200 scfm landfill gas compressor which raises gas pressure from -30 in. water column at inlet to 90 psig, shown in Figure 2 below;
- A water/glycol refrigeration system to chill the compressed LFG to 40ºF, coupled with a heat exchanger to reheat the chilled gas to 40ºF above the dew point, shown in Figure 2 below;
- Stainless steel vessels containing activated carbon for siloxane removal, shown in Figure 3 below.

Figure 1 – Ten Capstone C30 MicroTurbines

Figure 2 – Fuel treatment system including compression and drying components

Figure 3 – Dual stainless steel siloxane filters in series

The 30 percent methane content at the flare station was below Capstone's 35 percent specification, resulting in a decision to intermix gas from ten higher-Btu LFG wells. A separate above-grade header was installed to connect these wells to the microturbine plant. In order to minimize any impacts to the well field that could result from any intermittent operation of the microturbine plant, two design features were implemented:

1) The dedicated header was interconnected to the existing primary header with a check valve. When the microturbine plant is operating the valve is closed and all available landfill gas is directed to the plant. If the array is shutdown, the valve will open and the landfill gas will be redirected to the flare station through the original header;

2) A bypass line was added to the LFG treatment skid to route excess landfill gas to the flare station. Regardless of load-following or full-load operation of the microturbine array, the same amount of LFG is extracted from the well field through the dedicated header.

Based on previous experience, SCS decided to utilize an industrial compressor to pressurize the LFG. An oil-flooded sliding vane compressor was selected in order to achieve the desired 90 psi pressure increase in a single stage. A water/glycol chiller and heat exchanger provide enhanced moisture removal from the LFG. Initial siloxane samples were taken from the wells indicated that the total siloxane level was 1.9 mg/m^3 or 200 ppb. A siloxane removal system consisting of stainless steel vessels and graphite-based material was installed to meet the Capstone fuel specification of less than 5 ppb total siloxanes. Carbon change out frequency is expected to be every six months.

The fuel treatment equipment including all non-utility electrical and control equipment were designed and constructed on one skid by SCS Energy. This allowed for assembly and initial testing to be completed off-site prior to delivery.

SCS Energy worked extensively with Capstone's open-communications control protocols to develop and extend the PLC-based monitoring and control network to include external equipment, principally the compression and pre- treatment skid.

Net of equipment donation by SCAQMD and state grants, total installed cost was under $400,000.

Plant Operation and Maintenance

The Calabasas microturbine plant began operation in mid-August, and has been operating for more than 3,500 hours with 98 percent availability. Some downtime consisted essentially of tuning the various fuel treatment components to provide the requisite fuel quality for proper microturbine operation:

- **Upgrading compressor operation to deliver higher flow at increased gas pressure.** The oil-flooded sliding vane compressor system was originally intended for 80 psi output. The system was adjusted to provide 90 psi. The vane compressor appears to require a significant derating from manufacture specifications when using media other than air at atmospheric conditions. In the case of Calabasas, the compressor is used to pull a vacuum on the well-field. The derating was noted during the start-up by reviewing pressure and flow trends with a varied number of turbines operating. Once the required increase in flow was determined, the compressor capacity was increased by modifying the pulley sizing.

- **Compressor Maintenance.** The compressor oil is replaced between each 1,000 to 1,500 hours of operation. During the oil change the complete system is shut-down and inspected. By sampling and analyzing the oil, the replacement frequency can be optimized.

- **Siloxane filter maintenance.** The graphite media in the siloxane filters is expected to last six months before siloxanes break through at detectable levels. Complete carbon change out will take four hours.

- **Microturbine Review and Testing.** Due to close proximity to Capstone's offices, the ten Calabasas microturbines are utilized for review and testing of fuel pressure requirements, fuel system improvements, controls, and miscellaneous parts. Although minimized, these actions result in some downtime.

Additional operational enhancements included:

- **PLC-based control system implemented with the installation of Modbus translators.** The SCS-provided touchscreen PLC controller governs operation of the entire microturbine array and the fuel treatment system. Capstone products typically communicate using a RS-232 protocol through proprietary remote monitoring software. With the installation of Modbus translators in each of the units, a facility-wide control and monitoring system was implemented that includes the microturbines, the pre-treatment system, and the on-site power requirements.

- **Feedback for Fuel Treatment.** Since the gas dryer is critical to the fuel treatment equation, it was considered critical that the microturbines and the pre-treatment system communicate. This would limit exposure to out-of-spec fuel input that could hamper operation reliability or potentially could negatively impact internal fuel system components.

NEWLY COMMISSIONED AND UPCOMING

At the Rutgers University EcoComplex shown in Figure 4 below, an array of microturbines is currently converting LFG into two energy forms being used at the center: electricity and heat. In addition to power, exhaust from the microturbines heats water that is used in hydroponics greenhouse, a desalinization unit, and warm-water aquaculture tanks. The exhaust, which is uncontaminated by oil or other fluid vapor, is even used directly to provide CO_2 enrichment for enhanced hydroponics vegetable growth.

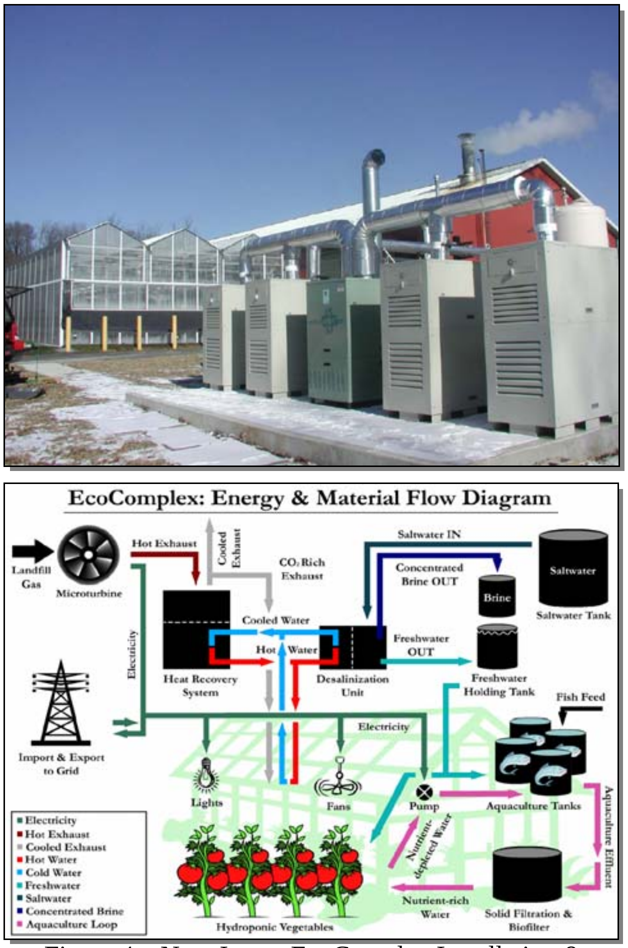

Figure 4 – New Jersey EcoComplex Installation & Schematic

In Illinois, a 12-microturbine array is due to go online in April 2003 at a landfill situated near a high school. Heat from the LFG-fueled MicroTurbines will serve hot water needs at the school while power not utilized at the campus (particularly overnight) will be exported to the Commonwealth Edison grid.

Three other landfill installations of Capstone microturbines are underway: a single-engine installation in Florida and an 8-unit deployment at each of two different Wisconsin landfills.

CONCLUSIONS & RECOMMENDATIONS

Microturbines can satisfy a niche in the distributed generation market, and can be successfully operated on landfill gas. As with all new technologies, there are questions as to long-term reliability and operation costs. These risks can be mitigated by owners/operators of microturbine projects by pursuing projects with the most rapid rates of return.

In particular for Calabasas Landfill, the project partners have learned the following details during the operation of the microturbines:

- Fuel compressor should ideally deliver 100 psig to surmount fuel train pressure losses while providing adequate fuel pressure to the microturbines.
- If a PLC is used as an additional layer of control over the microturbine array, Modbus translators used on individual microturbines can provide faster response and improved communications.
- The gas processing system should automatically shutdown if the refrigerated dryer/chiller is not operating to specification (e.g., chilled gas temperature rises above 50°F).

REFERENCES

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