Case Study:
King County South Treatment Plant
Renton, Washington

Combined heat and power using a molten carbonate fuel cell – 1.0 Megawatt of electrical output (MWe)

July 2006
WSU EEP06-03
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Combined Heat and Power (CHP) Case Study
CHP Using a Molten Carbonate Fuel Cell
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This King County photo shows the electrical balance of plant.

Introduction

In the early to mid 1990s King County, Washington, began to evaluate the potential for employing molten carbonate fuel cells as a means of providing on site generation based upon anaerobic digester gas at their South Treatment Plant in Renton (a wastewater treatment facility). In the photo, the skid mounted inverter converts direct current (DC) current to alternating current (AC) power. The fuel cell stacks are located in the pressure vessel to the right of the photo.

King County has long been an innovator in energy efficiency and as early as approximately 1982 had installed water-to-water heat pumps that transferred heat from the plant effluent to the anaerobic digesters. By so doing, methane was no longer needed for heating purposes and instead was scrubbed and sold to the local natural gas

distribution company. King County felt that the development of a fuel cell based system would be an even better strategy to produce both power as well as heat. In 1997, they entered into an agreement with MC Power to pursue the development of a research and development (R&D) facility with a commitment for partial funding from the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). Unfortunately for all concerned, MC Power went into bankruptcy when the DOE decided in 1999 to downsize its molten carbonate fuel cell program and funding of future R&D work by MC Power was eliminated.

- Despite this initial set back, King County with continued support from EPA went out for bid to complete the project and eventually entered into an agreement with Fuel Cell Energy of Danbury, Connecticut, in 2000. The resulting King County Fuel Cell Demonstration Project is the world's largest demonstration project of a molten carbonate fuel cell using anaerobic digester gas. The demonstration project was commissioned in April 2004. The demonstration period ends in September 2006 at which time King County has the right take over and to continue to operate the project.

The objectives of the project are:

- Demonstrate that molten carbonate fuel cell technology can be adapted to use anaerobic digester gas as the fuel source; and
- Achieve a nominal plant power output target of 1 MWe (net AC) using either digester gas, scrubbed digester gas or pipeline natural gas. After the demonstration, King County has the potential to operate the power plant at 1.5 MWe by installing a larger fuel cell stack.

The participants in the project are:

- King County
- Fuel Cell Energy Inc.
- U.S. Environmental Protection Agency
- CH2M Hill
- Brown and Caldwell
- Hawk Mechanical

The project is being reviewed by a team of experts comprised of representatives of state and federal government, national laboratories, academia, and industry.

Site Description

The King County Department of Natural Resources South Treatment Plant is located in Renton, Washington, and is one of two major wastewater facilities serving the greater Seattle/Bellevue Area. The plant has undergone a number of expansions over the past two decades and now has a capacity of approximately 90 million gallons per day with ample room for further expansion should the need arise. The facility's electrical demand is approximately 5.5 to 7.5 MWe on an average basis. The plant has four anaerobic digesters with a total capacity of approximately 240 thousand gallons and a thermal

demand for the digesters of approximately 7,142 kilowatt-ton (kWt) or 174 million British Thermal Units (Btu) per hour. Total gas production from the digesters is approximately 1,200 cubic feet/day with an average Btu content of 548 Btu/cubic foot.

Market Segment Evaluation

A critical component of the initial evaluation of the use of a molten carbonate fuel cell(s) at the Renton facility was a national assessment of the potential for employing such technology at similar facilities throughout the United States. In order to ascertain the market potential, MC Power contracted with engineering firm CH2M Hill in 1997 to conduct a national survey. CH2M Hill identified a total of 134 wastewater treatment facilities having a potential for the generation of 347 to 425 MWe.

Technical Description

The 1 MWe molten carbonate fuel cell demonstration project has as its primary objectives:

1. Demonstrate that molten carbonate fuel cell technology can be adapted to use anaerobic digester gas as a fuel source; and
2. Achieve a nominal power plant output target of 1 MWe (net AC) using either digester gas, scrubbed digester gas or pipeline natural gas.

As a pilot project the facility was intended to provide only a small percentage of the electrical and thermal requirements of the wastewater facility.
Total electrical demand for the facility is 5.5 to7.5 MWe and the total demand is 174 million Btu per hour.
The project is designed to provide on site power and thermal energy without any export to the local utility. Also because of the nature of any demonstration project the system requires total backup by Puget Sound Energy the serving utility.
The molten carbonate fuel cell is being operated on utility-provided natural gas, scrubbed anaerobic digester gas and un-scrubbed digester gas (sulfur is removed from the digester gas).
Thermal energy from the molten carbonate fuel cell is available in the form of hot water up to 1.4 million Btu (MMBtu) per hour is available for use in heating the digesters. A molten carbonate fuel cell needs the incoming fuel to be about 1200 degrees Fahrenheit (the fuel cell's operating temperature).
The heat recovery unit is designed to run when the fuel cell is generating power, not under hot standby or startup conditions. The hot water loop pumps, control valves and the blower are all fully automated.

- Incoming air temperature to the boiler is 580° F.
- Outgoing air temperature for the boilers is 240° F (change in temperature equals 340° F).
- Incoming water temperature for the main system in tunnel is 136° F.
- Outgoing boiler water temperature is 154° F (change in temperature equals 18° F.

The fuel supply to the fuel cell is as follows:

1. Gas #1 = Natural gas from King County: Anaerobic digester gas that has been scrubbed on-site to pipeline quality gas.
2. Gas #2 = Natural gas from Puget Sound Energy: Natural gas supplied by the local gas utility.
3. Gas #3 = Raw digester gas: Unscrubbed anaerobic digester gas from the digester gas scrubber header (only sulfur is removed).

Each supply source is part of the demonstration. An input flow of approximately 149 cubic feet per minute (cfm) is required from gases 1 and 2 to achieve the fuel cell rated output of 1 MWe, while approximately 227 cfm is required for gas 3 to achieve the same rated output. The natural gas has a measured lower heating value (LHV) of 900 Btu/cubic foot and the LHV for the digester gas is 548 Btu/cubic foot un-scrubbed.

System Efficiency

System efficiencies with heat recovery range from 60 to 65 percent. Electrical efficiency is from 43 to 47 percent (lower heating value). The 1 MWe of net power output is de-rated by 2 percent every six months as fuel cell stacks age.

Parasitic Loads

Gas Type	Balance of plant loads/kWe	Transformer/inverter loss/kWe	Total kWe
Natural Gas	*48-53*	*37*	*85- 90*
Digester Gas	*55-75 (including compressor)**	*37*	*92-112*

* The digester gas has an additional load for the gas compressor of about 40 kWe.

Performance Summary

Fuel Cell Performance Summary on Natural Gas

Year	2004		2005		
Parameter	**Q2&Q3**	**Q4**	**Q1**	**Q2**	**Q3**
Run Time Hrs	1,897	970	730	1,115	0
Power Gen KWh	1.4 M	0.5934	0.6974	1.1M	0
Availability	93%	100%	100%	84%	76%
Shut Down	7%	0%	0%	16%	24%
*Efficiency**	43%	43%	42%	43%	NA

**Based on electricity out/natural gas in.*

Fuel Cell Performance on Digester Gas

Year	2004		2005		
Parameter	**Q2&Q3**	**Q4**	**Q1**	**Q2**	**Q3**
Run Time Hrs	313	490	1,270	691	0
Power Gen Kwh	76,664	357,000	1.158M	489k	0
Availability	65%	95%	90%	94%	76%
Shut Down	35%	5%	10%	6%	24%
*Efficiency**	44%	44%	43%	44%	NA

**Efficiency based on electricity out/natural gas in.*

Project Cost

Total cost for the project exceeds 22.5 million dollars. However, much of that cost is due to the research and demonstration nature of this project and requirements for instrumentation and monitoring. According to Greg Bush, the King Country Project Manager, a similar facility could be delivered at approximately 5 million dollars.

Operation and Maintenance Issues

This King County photo shows the sulfa-treat vessels (for digester gas scrubbing).

A number of operation and maintenance issues have been identified to date during the startup and initial operation of the fuel cell plant.
Of particular note have been issues related to the various gas supplies. Since the fuel cell is being tested using three different gas supplies it has been necessary to make certain modifications to the facility to deal with the varying chemical compositions of the gases. In the case of the gas delivered by the local distribution company, it was learned that the gas contained unusually high amounts of carbonyl sulfide (COS). This required the addition of a third cold gas desulfurizer vessel.
When the scrubbed digester gas was used and it did not meet the utilities specifications it was returned to the header causing a rapid spike in the methane concentration of raw

digester gas. The rapid spike caused a system shutdown as a safety precaution. This could be remedied by the addition of a new pipeline directly from the digesters.
Several changes to the facility have also been made to facilitate maintenance. These include addition of platforms and ladders to provide better and safer access; addition of water booster pumps for potable water for gas humidification; revisions to control and logic to incorporate capability of managing plant response to gas diverts; and repairs related to a gasket leak at the fuel gas deoxidizer flange.
Facility staff training in operation and maintenance procedures took approximately one year after initial operation.
Another major operational issue has been achieving full remote operation of the facility from the offices of Fuel Cell Energy in Danbury, Connecticut. This will allow Fuel Cell Energy to provide continued oversight and assistance throughout the transition period to local operational staff and beyond.

Interconnection Issues

King County experienced a number of interconnection problems prior to reaching agreement with the serving utility resulting in the need for extra relay protection for the facility. Such problems caused delays in completion of the project and extra costs were incurred.

Environmental Issues

More than 90 percent of the wastewater treatment plants in the United States generate anaerobic digester gas (ADG) as a byproduct of the sewerage treatment process. ADG is a mixture of gases, mainly methane (ca 60 percent), carbon dioxide (CO2) and water vapor. When ADG is released uncombusted, it contributes significantly to the greenhouse effect–methane having an impact some 23 times that of carbon dioxide.
When ADG is flared, the combustion generates photoreactive ozone precursors such as nitric oxides and volatile organic compounds.
Fuel cells emit much smaller amounts of such nitric oxides (NOx) and volatile organic compounds. The Renton Molten Carbonate Fuel Cell project is designed to achieve the following emission goals:

- Carbon monoxide (CO) less than 10 parts per million (ppm) Volume
- NOx less than 2 ppm Volume
- Non-Methane Hydrocarbons (NMHC) less than 1 ppm Volume

To date the facilities emissions are as follows:

- CO less than or equal to 13 ppm
- NOx less than or equal to 0.2 ppm
- NMHC none detected

Next Steps

King County hopes to complete the demonstration in September 2006 with report writing to follow. Upon completion of the demonstration, King County intends to continue to

operate the fuel cell. For further information see King County's library of information at http://dnr.metrokc.gov/wtd/fuelcell/library.htm.

Acknowledgements

The Northwest CHP Application Center wishes to especially thank the staff of King County and in particular Greg Bush for their persistence and hard work throughout the demonstration period.

Northwest CHP Application Center

For further information about the Northwest CHP Application Center please visit our website www.chpcenternw.org/ or contact Dave Sjoding at 360.956-2004 or sjodingd@energy.wsu.edu.