National Renewable Energy Laboratory
Innovation for Our Energy Future

Fuel Cells on Bio-Gas

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Wastewater Treatment Plants

- WWTP operators are looking for opportunities to utilize biogas as a **renewable energy source**.
- Majority use biogas through boilers for reheating
- Interest is growing in distributed generation, especially where both electricity and fuel costs are high.
- Drivers for the decision to purchase fuel cells
  - Reliability
  - Capital and O&M costs
  - Availability of Government Incentives

Anaerobic Digestion and Biogas

- Anaerobic digestion is a process used to stabilize wastewater sludge before final disposal.
- The process uses microorganisms in the absence of oxygen to convert organic materials to biogas.

Range of Biogas Compositions

Methane	50% – 75%
Carbon Dioxide	25% – 50%
Nitrogen	0% – 10%
Hydrogen	0% – 1%
Sulfur Species	0% – 3%
Oxygen	0% – 2%

WWTP Co-Gen Market

- There are over 16,800 WWTP in the U.S.
- 615 facilities with flows > 3 mgd that use anaerobic digestion
- 215 do not use their biogas but flare it instead.
- California has the highest number of municipal facilities using anaerobic digestion, about 102, of which 25 do not use their biogas.

Case Study: City of Tulare

Facility size:	11.5 million gallons per day
Biogas generated:	600,000 SCF per day
Fuel cells:	Three 300-kW units from FCE
Gas cleanup:	Applied Filter Technology

Startup: September 2007

Total Cost: $7 million

State & Federal Incentives: $4.05 million

Cost to City: $2.95 million

Payback Period: 4.5 years

Photo courtesy of City of Tulare.

Fuel Cell Value Proposition

- **Increased energy efficiency**
  - 42% to 47% net electrical efficiency
  - Cogenerate heat to offset natural gas purchase
  - Combined electric + heat ≈ 80% efficient
- **Emissions savings**
  - Low NOx and SOx
  - 40% lower GHG emissions compared to grid
- **High availability and reliability**
  - Single unit availability > 97%
  - Multiple unit availability exceeds five 9's.

Fuel Cell Products

- There are two U.S. manufacturers with a track record for supplying fuel cell power plants for use with anaerobic digesters gas.
- **FuelCell Energy, Inc.** (Molten Carbonate Technology)
  - Danbury, Connecticut
  - Power Plants Sizes: 300 kW, 1.4 MW, and 2.8 MW
- **UTC Power, Inc.** (Phosphoric Acid Technology)
  - South Windsor, Connecticut
  - Power Plant Size: 400 kW

UTC Power PureCell® Model 400

New Product

- 400-kW electric output
- Natural gas/ADG
- 42% electrical efficiency*
- 1.7 MMBtu/hr heat output (60°C)
- Up to 85% system efficiency
- Meets CARB 2007 standard
- 20-year powerplant life**
- Modular approach for MW-size applications

* LHV at beginning of life
** with overhaul at end of year 10

FuelCell Energy DFC 1500

- 1.4-MW electric output
- Natural gas/ADG
- 47% electrical efficiency*
- 2.7 MMBtu/hr heat output at 60°C (0.5 MMBtu/hr at 300°C)
- Up to 74% system efficiency
- Meets CARB 2007 standard
- 20-year powerplant life**

* LHV at beginning of life
** with overhaul at end of year 5

Analysis: 30 MGD WWTP serving 300,000

110 million SCF/year of biogas (Reference 1)

Technology	UTC PAFC	FCE MCFC	Micro-turbine	Recip. engine
Capacity supported by bio-gas*	**880 kW**	**1,100 kW**	**570 kW**	**470 kW**
Energy produced MW-hr/yr	**7,700**	**9,150**	**5,000**	**4,110**
Capital costs $/kW (current)	**$4,500**	**$4,300**	**$3,840**	**$2,870**
Capital costs (promised)	**$1,500**	**$2,500**		

Without incentives

* Assumes full use of bio-gas without regard to generator unit size

What's Next? Tri-Generation

Heat,
Hydrogen,
& Electricity
On-Site

DFC Power Plant	Electrical Output [kW]*	Hydrogen Produced [lbs/day]	Vehicles Supported at 1GGE/day
DFC-300	250 kW	300	~130
DFC-1500	1000 kW	1,200	~540

* Note: H_2 is produced at the expense of electricity production efficiency.

H_2 at WWTP can promote the fuel cell vehicles.

H_2 can be used on-site for fueling a municipal vehicle fleet or can be offered for sale to the public.

Fuel Cell-Powered Forklifts Are Here Now

Hydrogen fuel cells are a viable, cost-effective solution for material handling equipment.

- Allow for rapid refueling
- Provide constant power during use
- Eliminate need for space for battery storage and chargers

Fuel Cell Forklifts are in place today.

- Chicago-based Central Grocers announced purchase of **220 fuel cell lifts** from Plug Power in 12/08.
- DoD's Defense Logistics Agency is beginning a three-year fuel cell forklift pilot project that will place 100 fuel cell lifts in four distribution centers.

DOE has issued an RFI seeking input in five topic areas for future RD&D.

1. Early Fuel Cell Market Applications with High Volume Potential
2. Integrated Renewable Hydrogen Systems and Public-Private Community-Based Partnerships
3. **Using Biogas and Fuel Cells for Co-Production of On-Site Power and Hydrogen**
4. Combined Heat and Power (CHP) Fuel Cell Systems
5. Using Combined Heat, Hydrogen, and Power (CHHP) Systems to Co-Produce and Deploy Hydrogen to Early Market Customers

Summary Conclusions

- Fuel cells operating on bio-gas offer a pathway to renewable electricity generation.
- With federal incentives of $3,500/kW or 30% of the project costs, reasonable payback periods of less than five years can be achieved.
- Tri-generation of electricity, heat, and hydrogen offers an alternative route to solving the H_2 infrastructure problem facing fuel cell vehicle deployment.
- DOE will be promoting bio-gas fuel cells in the future under its Market Transformation Programs.

References Cited

Reference 1

"Analysis and Opportunity for Fuel Cell Application at Data Centers and Wastewater Treatment Plants," Mahadevan, K.; Judd, K.; Boczek, B.; Leibrand, A.; and Sommer, A. Presented at the 2008 Fuel Cell Seminar, Phoenix, Arizona, October 29, 2008.