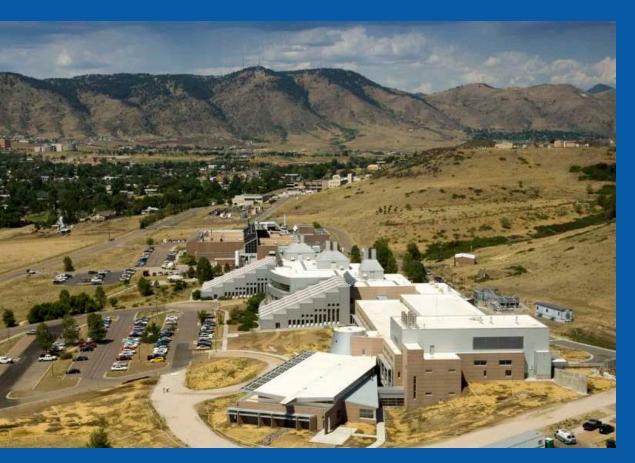
# **Fuel Cells on Bio-Gas**



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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 Sulfur Species	0% – 1% 0% – 3%			
Oxygen	0% – 3%			
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## **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



# **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

<sup>\*</sup> LHV at beginning of life

<sup>\*\*</sup> 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\*\*



<sup>\*</sup> LHV at beginning of life

<sup>\*\*</sup> 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	\$4,500	\$4,300	\$3,840	\$2,870
costs \$/kW (current)	W			
Capital costs (promised)	\$1,500	\$2,500		

<sup>\*</sup> 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		Vehicles Supported at
1 Idile	[kW]*		1GGE/day
<b>DFC-300</b>	250 kW	300	~130
<b>DFC-1500</b>	1000 kW	1,200	~540

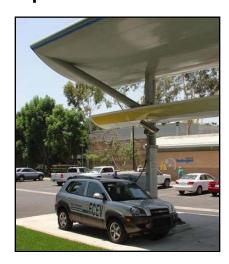
<sup>\*</sup> Note: H<sub>2</sub> is produced at the expense of electricity production efficiency.

## H<sub>2</sub> at WWTP can promote the fuel cell vehicles.

H<sub>2</sub> 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, costeffective 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.

- 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
- 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<sub>2</sub> 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.