City of Tulare
Renewable Biogas Fuel Cell Project

Go Local: Maximizing Your Local Renewable Resources With Fuel Cells

August 16, 2011
Presentation Outline

- Background
- Digester gas fuel cells
- Why fuel cells for Tulare
- Tulare Fuel Cell Cogeneration Project
- Digester gas treatment
- Tulare fuel cell operating experience
- Questions/answers
Equalization Basins

Headworks

BVF

FOG DAF

Flow split

Sequential Batch Reactors

SBR Pumps

SBR Pumps

Sludge DAFs

Denite Filters

FOG/Sludge Digesters

Blowers
City of Tulare WWTP Data

- Plant Flow – 4.4 mgd domestic + 7.1 mgd industrial = 11.5 mgd total
- Digester Gas Production ~ 500,000 scfd
- Most Digester Gas Produced in Bulk Volume Fermentor (BVF)
- Average Electrical Demand – 2,700 kW
Fuel Cells

- Run on wastewater digester gas, previously burned in a flare.
- Air District permits are easy and fast.
- Generate 1,200 kW. Treatment plant uses 2,700 kW. Generate about $3,200 worth of electricity per day.
- Four fuel cells cost $9.39 million.
- Received $4.95 million incentive payment from Southern California Edison.
Fuel Cells – Greenest Use of Digester Gas

- Highest Efficiency available for power generation equipment (47%)
- Exempt from air permit requirements*
- Reduction of greenhouse gases
- CARB ’07 Certification pending for digester gas

*Exempt is a strong word, and unfortunately, has not been the absolute truth.

Permitting agencies have required permits; although requirements are minor.
Fuel Cells – Other Benefits

- Qualifies for simplified interconnection
  - California Rule 21 Compliant

- Self Generation Incentive Program (SGIP) grant money currently available
  - SGIP currently only for Fuel Cell and Wind Projects
  - $4,500/kW for up to 1MW
    - $2,250/kW for 2nd MW
    - $1,125/kW for 3rd MW
Design/build

Conventional – Design – Bid – Build

Power Purchase Agreement (PPA) by third party Design – Bid – Build – Own – Operate (DBOO)

Design/build method was selected by City of Tulare
## Comparison of Design/Build Proposals

<table>
<thead>
<tr>
<th>kW Rating</th>
<th>Proposed Equipment</th>
<th>Turnkey Cost</th>
<th>Grant</th>
<th>Net Construct Cost</th>
<th>Five Year Engine Maint</th>
<th>Five Year Gas Skid Maint</th>
<th>Emission Offsets</th>
<th>Five Year Cost</th>
<th>Generated Energy Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>750</td>
<td>Fuel Cell Energy DFC 300MA Fuel Cells</td>
<td>5,182,545</td>
<td>3,375,000</td>
<td>1,807,545</td>
<td>1,092,848</td>
<td>500,500</td>
<td>0</td>
<td>3,400,893</td>
<td>727,299</td>
</tr>
<tr>
<td>750</td>
<td>Deutz 616 V16 Lean Burner IC Engine</td>
<td>2,567,749</td>
<td>750,000</td>
<td>1,817,749</td>
<td>537,650</td>
<td>765,000</td>
<td>71,943</td>
<td>3,192,342</td>
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<tr>
<td>848</td>
<td>GE Jenbacher Model JGC316 IC Engine</td>
<td>4,147,000</td>
<td>848,000</td>
<td>3,299,000</td>
<td>458,114</td>
<td>500,500</td>
<td>71,943</td>
<td>4,329,557</td>
<td>776,648</td>
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<tr>
<td>750</td>
<td>Ingersol Rand 250ST Microturbines</td>
<td>4,493,000</td>
<td>975,000</td>
<td>3,518,000</td>
<td>412,020</td>
<td>500,800</td>
<td>12,000</td>
<td>4,442,520</td>
<td>595,308</td>
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<tr>
<td>750</td>
<td>Ingersol-Rand 250ST Microturbines</td>
<td>5,043,768</td>
<td>975,000</td>
<td>4,068,768</td>
<td>408,924</td>
<td>500,500</td>
<td>12,000</td>
<td>4,990,192</td>
<td>595,308</td>
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<td>750</td>
<td>Fuel Cell Energy DFC 300MA Fuel Cells</td>
<td>7,794,757</td>
<td>3,375,000</td>
<td>4,419,757</td>
<td>978,000</td>
<td>500,500</td>
<td>0</td>
<td>5,898,257</td>
<td>727,299</td>
</tr>
</tbody>
</table>
Tulare Fuel Cell Project Summary

- Three 300 kW FCE 300MA units
  - 4th unit is now in operation
- Digester gas treatment system by Applied Filter Technology (AFT), Snohomish WA
  - H₂S, siloxanes, moisture, VOC, etc.
- Electrical interface with utility
- Hot water heat recovery
- Alliance Chico Energy did design/build
Digester Gas Treatment System

- Packed tower water scrubber for $\text{H}_2\text{S}$ reduction
- Iron sponge for $\text{H}_2\text{S}$ removal
- Particulate filter – compressors – heat exchanger
- Chiller – removes water plus some $\text{H}_2\text{S}$ and siloxanes
- Carbon adsorbers for siloxane and VOC removal
Plan View – Tulare Fuel Cell Facility
Plan View – Digester Gas Treatment Area

- Carbon Absorbers for Siloxane and VOC Removal
- Heat Exchanger
- Moisture Separator
- Compressors
- Particulate Filter
- Iron Sponge for H₂S Removal
- Water Scrubbers for H₂S Reduction
- Chiller
City of Tulare
Anaerobic Digester Gas
FuelCell Energy Fuel Cells
900 kW

450 kW Waukesha Engine Generator

Solar PV Carport

300 kW Fuel Cells

Flare
Packed Wash Tower
Gas Chiller
H2S Removal
Siloxane Removal
Compressor Skid

San Joaquin Valley APCD Permits

- Permit to construct and permit to operate in lb/MWh
  
  \[
  \begin{align*}
  NO_X &= 0.02 \\
  SO_X &= 0.001 \\
  PM_{10} &= 0.01 \\
  CO &= 0.05 \\
  VOC &= 0.02
  \end{align*}
  \]
Operating Data

- Actual kW produced
  DC = 335   AC = 300

- Actual fuel cell availability factor in 2010 94.5%
<table>
<thead>
<tr>
<th>Component</th>
<th>Maintenance</th>
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</thead>
<tbody>
<tr>
<td>Every 3 Months: <em>(May be performed on-line)</em></td>
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<tr>
<td>Water Treatment System (WTS) Brine Tank</td>
<td>Replenish salt</td>
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<tr>
<td>Recycle Blower</td>
<td>Grease motor bearings</td>
</tr>
<tr>
<td>WTS Multimedia Filter</td>
<td>Replace (if required)</td>
</tr>
<tr>
<td>WTS Carbon Filter</td>
<td>Replace (if required)</td>
</tr>
<tr>
<td>EBOP Ventilation Filters</td>
<td>Clean and Inspect (every 3 months for first six months)</td>
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<tr>
<td>Chemical Injection Storage Tank (2-pass RO system only)</td>
<td>Check level and refill (if required)</td>
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<tr>
<td>Every 6 Months: <em>(May be performed on-line)</em></td>
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<tr>
<td>WTS RO Pre-Filter (N/A on 2-pass RO system)</td>
<td>Replace (Also replace if D/P exceeds 22 psig)</td>
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<tr>
<td>Recycle Blower</td>
<td>Replace rotor bearing grease cartridge (if required)</td>
</tr>
<tr>
<td>Fresh Air Blower Intake Filter</td>
<td>Replace (Also replace if D/P exceeds 10 IWC)</td>
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<tr>
<td>EBOP Ventilation Filters</td>
<td>Clean and Inspect (every 6 months after the first 6 months)</td>
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<tr>
<td>Every 12 Months: <em>(May be performed on-line)</em></td>
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<tr>
<td>WTS RO Pump</td>
<td>Replace pump(s)</td>
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<tr>
<td>Every 18 Months: <em>(Requires a shut-down)</em></td>
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<tr>
<td>Fuel Gas Strainer</td>
<td>Clean, inspect, (remove if required)</td>
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<tr>
<td>EBOP Compartments</td>
<td>Clean, inspect</td>
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<tr>
<td>Every 36 Months: <em>(Requires a shut-down)</em></td>
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<tr>
<td>Desulfurizer Afterfilter</td>
<td>Replace (Also replace if D/P exceeds 1.0 psig)</td>
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<tr>
<td>Preconverter/Deoxidizer</td>
<td>Replace catalyst (if required)</td>
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<td>Every 72 Months: <em>(May be performed on-line)</em></td>
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<tr>
<td>WTS Electronic De-Ionization Unit</td>
<td>Replace</td>
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<tr>
<td>WTS Final Polishing Filter</td>
<td>Replace (Also replace if D/P exceeds 15 psig)</td>
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</table>
Lessons Learned

- Design/build – Get your attorney involved early

- Include a load bank (4th fuel cell) or Advanced Energy Storage (coming) in the design

- Gas treatment system availability is critical. Run on natural gas if gas treatment fails, to keep fuel cells generating.
Three Year Report

<table>
<thead>
<tr>
<th>Period</th>
<th>(1) Percent System Availability</th>
<th>(2) Percent Fuel Cell Availability</th>
<th>kWhrs Generated</th>
<th>Fuel Cell Maint. Agreement</th>
<th>Gas Skid Maint. Agreement</th>
<th>$ per kWhr</th>
<th>Cost to Purchase Generated kWhr @ $0.11</th>
<th>Operational Savings</th>
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<tr>
<td>1/1/08</td>
<td>86.3</td>
<td>98.5</td>
<td>6,312,550</td>
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<td>1/1/09</td>
<td>76.4</td>
<td>89.4</td>
<td>4,725,000</td>
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<td>$290,849</td>
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<tr>
<td>1/1/10</td>
<td>94.5</td>
<td>94.5</td>
<td>8,158,800</td>
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<td>$290,849</td>
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</tr>
</tbody>
</table>

(1) No digester gas available for seven weeks while BVF was cleaned in 2009, two fuel cell stacks replaced.

(2) Two fuel cell stacks replaced in 2009 due to frequent unscheduled cool downs caused by gas scrubber, third fuel cell availability was 98.7%.
Summary

- Fuel cell is the cleanest, most efficient cogeneration technology for digester gas.

- Financially, fuel cell technology competes well with engines and turbines based on the incentive money available in California. Project cost $9.39 million, SGIP grants of $4.95 million.

- You won’t have to worry about the future changes in emissions regulations.
Permitting is relatively easy
Utility coordination for interconnection is relatively simple and quick
Low operator attention for maintenance
Run on natural gas if biogas system fails!
Questions?

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