Fuel Cell Power Plants
Biofuel Case Study – Tulare, CA

DOE-NREL Workshop
Golden, CO
June 11-13, 2012

reliable, efficient, ultra-clean
Integrated Fuel Cell Company

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>Sell (direct &amp; via partners)</th>
<th>Install</th>
<th>Services</th>
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Growing Market Presence

- 180 MW installed and in backlog
- Over 80 Direct FuelCell® plants generating power at more than 50 sites globally
- Providing:
  - On-site power
  - Utility grid support

Delivering ultra-clean baseload distributed generation globally

- 600 kW plant at a food processor
- 1.4 MW plant at a municipal building
- 2.4 MW plant owned by an Independent power producer
- 11.2 MW plant - largest fuel cell park in the world
• More power for given amount of biogas: Higher efficiency than any other generation at typical digester facility sizes

• Good heat to power ratio for digester support: Fuel cell makes enough heat to support digester operation

• Avoids generation of NOX and other pollutants from flare or from other generation technologies
Non-Municipal Applications

• Fuel Resource Diversity
  – Waste from food and beverage processing
  – Waste from other commercial processes
    • Biofuel production
    • Pharmaceutical Organics

• Other Factors
  – Access to Federal Tax Credits
  – Often smaller scale than municipal applications
  – Often not 24 x 7 operation, requiring alternate fuel for weekend operation
## Typical Fuels Composition

<table>
<thead>
<tr>
<th>Composition</th>
<th>Natural Gas</th>
<th>Biogases</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Waste Water</td>
</tr>
<tr>
<td>Methane (Vol%)</td>
<td>80-100</td>
<td>~50-60</td>
</tr>
<tr>
<td>Carbon Dioxide (Vol%)</td>
<td>&lt;3</td>
<td>30-40</td>
</tr>
<tr>
<td>Nitrogen (Vol%)</td>
<td>&lt;3</td>
<td>&lt;4</td>
</tr>
<tr>
<td>Oxygen (Vol%)</td>
<td>&lt;0.2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>H₂S, ppm</td>
<td>&lt;0.1</td>
<td>&lt;400</td>
</tr>
<tr>
<td>Non-H₂S Sulfur, ppm</td>
<td>&lt;10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Halogens, ppm</td>
<td>&lt;0.1</td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Moisture, %</td>
<td>&lt;0.02</td>
<td>~3</td>
</tr>
</tbody>
</table>
Natural Gas
• 90 – 100 % Methane, balance typically higher hydrocarbons
• 900 – 1000 Btu/ft³
• Dry
• Very Low Oxygen, except peak shave gas
• Odorized for safety, typically 3 ppm sulfur, max 20 ppm

Digester Gas
• 50% - 80% Methane (60% typical), balance typically CO₂
• 500 – 800 Btu, ft³
• Saturated at digester temperature
• Fraction to a few percent Oxygen
• Sulfur present naturally, at tens to hundreds of ppm, also often contains Siloxanes
- Plant Flow – 11.5 MGD
- Digester Gas Production 500,000 SCFD
- Production of Biogas in Bulk Volume Fermentor (BVF)
- Electrical Demand 2,700 KW
Tulare CA WWTP
Fuel Cell Plant

- 4 FCE DFC300 Fuel Cells 1200 KW (3 initial in 2008, 4th added in 2011)
- Biogas Treatment by Applied Filter Technology (H₂S, Siloxanes and VOC)
- CHP (Hot Water) Heat Recovery
- Electric Interface with Utility (SoCal Edison)
Tulare CA WWTP
Fuel Cell and Ancillary Systems

City of Tulare
Anaerobic Digester Gas
FuelCell Energy Fuel Cells
900 kW

- Flare
- Packed Wash Tower
- Solar PV Carport
- Gas Chiller
- H2S Removal
- Siloxane Removal
- Compressor Skid
- 450 kW Waukesha Engine Generator
- 300 kW Fuel Cells
Tulare CA WWTP

Key Drivers for Fuel Cell

- Digester Gas Previously Flared
- Highest Efficiency Available (47%) for power generation
- Reduce Greenhouse gasses
- Emissions Exemptions and Rule 21 Qualification
- SGIP funding
- Dual Fuel (Natural Gas) Flexibility
DFC 300 CHP, 1MW, digester biofuel and natural gas
Food Processing Facility
Gills Onions Oxnard, CA

600 KW DFC 300 Units, digester fuel, combined heat and power
Market Drivers
Municipal and Industrial Facilities face disposal issues, a need for clean power to comply with clean air regulations, and ambitious sustainability goals

Fuel Cell Plants Provide Solutions
- Renewable baseload power solves waste disposal problem and provides continuous clean power
- Ultra-clean power facilitates ease of air permitting
- Distributed generation enhances power reliability and energy security
- High efficiency

Fuel Flexibility on varying BTU Gas
- Municipal Wastewater Biogas
- Brewery and Food and Animal Waste
- Biogasifier and Biofuel waste gas

Site Challenges need to be Addressed in Design
- Clean up systems required
- Varying biofuel availability