The Power of Digester Gas: A Technology Review from Micro to Megawatts

Mark McDannel

Los Angeles County Sanitation Districts
Energy Recovery Engineering Section

SCAP POTW Energy Management Committee
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Presentation Overview

- Overview of Sanitation Districts Biogas Facilities
- Why Self Generation?
- Generation Equipment
- Digester Gas Cleaning
- Capital and Operating Costs
Districts Energy Management Program

- Maximum development of bio-gas resources
- Minimize energy usage
- Minimize procurement cost and maximize sales income
- Demonstrate new technologies that reduce air emissions
So. Cal. Edison Electric Grid

127 MW Generated By Districts’ Facilities

98 MW

29 MW

Districts’ Facilities (use 41 MW)

12 MW

So. Cal. Edison Electric Grid

Diagram showing the flow of 127 MW generated by Districts’ Facilities, 29 MW for Districts’ Facilities use, and 12 MW sent to So. Cal. Edison Electric Grid.
IC POWER ENGINE INSTALLED at JWPCP in 1938
JWPCP Total Energy Facility

Location - Carson, California
Combined Cycle Cogeneration Power Plant

- (3) 9 MW Solar Mars T-13000 gas turbine generators
- (1) 3 MW DeLaval HJ T steam turbine generator
IC Engine Cogeneration Facility at Valencia WRP

Location - Valencia, CA

- 500 kw Cooper-Superior Model 6GTLA Engine Generator
- Steam used to heat digesters
Puente Hills Gas-to-Energy Facility
# Biogas Power Production

<table>
<thead>
<tr>
<th>FACILITY</th>
<th>POWER PRODUCTION TECHNOLOGY/ (FUEL)</th>
<th>NET POWER PRODUCED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint WPCP</td>
<td>CC Gas Turbine(Digester Gas)</td>
<td>22 MW</td>
</tr>
<tr>
<td>Valencia WRP</td>
<td>IC Engine (Digester Gas)</td>
<td>400 kW</td>
</tr>
<tr>
<td>Puente Hills LF</td>
<td>Steam Boiler/Turbine (LFG)</td>
<td>46 MW</td>
</tr>
<tr>
<td>Palos Verdes LF</td>
<td>Steam Boiler/Turbine (LFG)</td>
<td>4 MW</td>
</tr>
<tr>
<td>Spadra LF</td>
<td>Steam Boiler/Turbine (LFG)</td>
<td>8 MW</td>
</tr>
<tr>
<td>Puente Hills LF</td>
<td>Gas Turbine (standby) (LFG)</td>
<td>0 MW</td>
</tr>
<tr>
<td>Calabasas Landfill</td>
<td>Capstone Microturbines (LFG)</td>
<td>250 kW</td>
</tr>
<tr>
<td>Lancaster WRP</td>
<td>Ingersoll-Rand Microturbine (DG)</td>
<td>225 kW</td>
</tr>
<tr>
<td>Palmdale WRP</td>
<td>Molten Carbonate Fuel Cell (DG)</td>
<td>225 kW</td>
</tr>
<tr>
<td>Puente Hills LF (2005)</td>
<td>IC Engine (LFG)</td>
<td>6 MW</td>
</tr>
<tr>
<td><strong>TOTAL BIOGAS GENERATION</strong></td>
<td></td>
<td>87 MW</td>
</tr>
</tbody>
</table>
Existing Districts Digester Gas-Fired Facilities

- Boilers
  - Digester Gas for Heating

- Turbines
  - J WPCP 22 MW (400 MGD)

- Engines
  - Valencia 0.4 MW (12.5 MGD)

- Microturbines
  - Lancaster 250 kW (10 MGD)

- Fuel Cell
  - Palmdale 250 kW (15 MGD)
Why Self Generation?

- Save Money on Power Purchases
- Increase reliability
  - Digester Heating (Cogeneration)
  - Increase Run Hours on Standby Generators
- Reduce Emissions
- Reduce Global Warming
# Generation Equipment

<table>
<thead>
<tr>
<th>Type</th>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>Gas Turbines</td>
<td>1 MW to 15 MW</td>
</tr>
<tr>
<td>IC Engines</td>
<td>25 kW to 3 MW</td>
</tr>
<tr>
<td>Fuel Cells</td>
<td>200 kW to 2 MW</td>
</tr>
<tr>
<td>Microturbines</td>
<td>30 kW to 250 kW</td>
</tr>
</tbody>
</table>
Gas Turbines

- Medium to High Efficiency
- Low Operating & Maintenance Cost
- Higher Installed Cost
- Excellent for Heat Recovery
- Island Operation
- Require Digester Gas Cleaning
## Gas Turbine Manufacturers

<table>
<thead>
<tr>
<th>Company</th>
<th>Models</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solar</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Titan</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Mars</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Taurus 60</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td>Centaur 40</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Mercury 50 (recuperated)</td>
<td>4.6</td>
</tr>
<tr>
<td><strong>Rolls-Royce, Siemens</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IC Engines

- Higher Air Emissions
  - SCAQMD Rule 1110.2 may kill market
- High Efficiency
- Inexpensive
- Suppliers
  - Waukesha
  - CAT
  - Jenbacher
  - Deutz
**IC Engines - Waukesha**

- 280 kW to 1,050 kW
- Older Tech. High emissions
- New High Efficiency Low Emissions Unit This Year
IC Engines - CAT

- 3516: 900 kW
- 3616: 3 MW
- 3520: 1.6 MW
Caterpillar G3616 Gas Engine
IC Engines - Others

- Jenbacher
- GE Energy
- Deutz
IC Engine Trends

- Higher Speeds (Increased Power Density)
- Reduce Air Emissions
- Increase Reliability
- Reduced Capital and Operating Costs
Fuel Cells

- Near Zero Air Emissions

- High Efficiency

- Expensive
  - Rebates available in some areas

- Two Suppliers
  - Fuel Cell Energy: 300 kW, 1 MW, 2 MW
  - UTC: 200 kW
Palmdale Fuel Cell Project

- Fuel Cell Energy molten carbonate fuel cell
- 250 kW, 47% efficiency (LHV)
- Heat recovery to heat water for digesters
- Combined heat and power efficiency 73%
- Startup completed Jan 2005
- Capital cost $1.9 million (before 50% rebate)
- 50% of cost recovered from SGIP
Fuel Cells – Operating Units on Digester Gas

**Fuel Cell Energy**
- Sanitation Districts: One 250 kW Unit
- Santa Barbara: Two 250 kW Units
- King County, Wash.: 1.0 MW
- Riverside, Ca.: 1.0 MW

**UTC**
- Las Virgenes: Two 200 kW Units
Microturbines

- Low Air Emissions
- Medium Efficiency – High Temperature Exhaust
- Cost Effective

Two Suppliers in California
- Capstone: 30 kW, 60 kW, 200 kW
- Ingersoll Rand: 70 kW, 250 kW
Lancaster Microturbine Project

- Ingersoll Rand microturbine
- 250 kW gross, 32% efficiency (LHV)
- Heat recovery to heat water for digesters
- Combined heat and power efficiency 51%
- Capital cost $684k
- 40% of cost recovered from California Self Generation Incentive Program (SGIP)
Calabasas Microturbine Facility
**Digester Gas Cleanup**

- Some technologies require removal of gas contaminants
- Can add up to 2 cents/kWhr to O&M costs
Siloxanes

- Organosilicon compounds present in waste water
- Oxidize to SiO₂ during combustion
- Engines and turbines-removal costs vs. O&M costs
- Engines w/ catalyst, recuperated turbines, fuel cells, microturbines require siloxane removal
Siloxane Removal

*Z* Sorbents
  - **Effective**
  - Need to monitor for breakthrough and replace sorbent

*Z* Deep Chilling
  - No longer considered commercially available

*Z* Pressure Swing Absorption
  - Continuous operation
  - Requires flaring of off gas, loss of 2-8% of fuel heating value
Sorbent Based Fuel Skid
Other Contaminants

- Fuel cell requires removal of sulfur compounds, VOCs, chlorinated VOCs
- Future application of catalysts on engines may require removal of S, Cl
<table>
<thead>
<tr>
<th>Power Generation Type</th>
<th>Installed Cost ($/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC Engines</td>
<td>$1,700</td>
</tr>
<tr>
<td>Gas Turbines</td>
<td>$2,000</td>
</tr>
<tr>
<td>Microturbines</td>
<td>$3,000</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>$8,500</td>
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</tbody>
</table>
## Summary Comparison

**Operating Cost, cents/kW-hr**

<table>
<thead>
<tr>
<th>Power Type</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Gas Turbines</td>
<td>1.0</td>
</tr>
<tr>
<td>IC Engines</td>
<td>1.5</td>
</tr>
<tr>
<td>Microturbines</td>
<td>1.6</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>3.5</td>
</tr>
</tbody>
</table>
**Summary Comparison**

**Power Production Cost, cents/kW-hr**

*(10 yr write-down @5%)*

<table>
<thead>
<tr>
<th>Power Source</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Gas Turbines</td>
<td>4</td>
</tr>
<tr>
<td>IC Engines</td>
<td>4</td>
</tr>
<tr>
<td>Microturbines</td>
<td>6</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>16</td>
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</tbody>
</table>
Conclusions

- Reduce Operating Costs
- Reduce Air Emissions
- Increase Reliability
- Gas Cleanup
Questions?

Mark McDannel

562-908-4288 x2442
mmcdannel@lacsd.org