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Presentation Outline

• Cogeneration – Background and Application
  • Historical Perspectives
  • Current Drivers
  • Cogeneration Systems & Considerations

• Cogeneration Case Studies
  • Fond du Lac, Wisconsin
  • Kankakee River Metropolitan Agency, Illinois
  • Dubuque, Iowa
Definitions & Clarifications

- **Cogeneration in this Discussion:**
  - Using biogas to produce electricity and recovering waste heat.
  - Assumes internal combustion engines or microturbines.
  - Others not considered: Stirling engines, fuel cells, organic Rankine cycle systems, etc.
Cogeneration Schematic
Biogas Historically Fired in Boilers and/or Flared

Raw Sludge → Heat → Digested Sludge → Biogas

Normally Minimal Conditioning Required
Biogas Cogeneration

Typically Significant Conditioning Required
• Moisture
• Hydrogen Sulfide
• Siloxanes
Historical Biogas Cogeneration

- **Pre-1970s:**
  - Electrical production typical only at large plants

- **1970 & early 1980s**
  - Grants + high energy costs
  - Cogeneration installed at many small WWTPs
  - Systems often not used because of high maintenance and operational costs

- **1990s:**
  - Low energy costs
  - Fewer cogeneration projects, except at larger plants
Current Biogas/COGEN Drivers

- High Energy Costs
- Potential Revenue from High-Strength Wastes
  - Additional biogas
  - Tipping fees
- Carbon Footprint/Green Considerations
- Improved Biogas Conditioning Systems
- “It’s the Right Thing To Do”
Keys For Cogen Viability

- Plant Size
- Plant Energy Balance – Heat Recovery
- Local Energy Costs
- Local Renewable Energy Value
- Local High-Strength Waste Availability/Aptility to Receive
- Biogas Quality
Generalized Cogen Viability
(Assuming biogas quality is not significantly worse than typical)

<table>
<thead>
<tr>
<th>Plant Size</th>
<th>Cogen Viable (Typically)</th>
<th>Cogen w/ Supplemental Feed Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5 mgd</td>
<td>No</td>
<td>Possible</td>
</tr>
<tr>
<td>5-15 mgd</td>
<td>Possible/Likely</td>
<td>Yes</td>
</tr>
<tr>
<td>&gt; 15 mgd</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
COGEN Viability – Size Matters

**Small WWTP**
- Capital Costs
- Revenue
- O&M Costs

**Larger WWTP**
- Capital Costs
- O&M Costs

**Time**
Comparison of Digester Gases

<table>
<thead>
<tr>
<th>Parameters</th>
<th>TCB, IL</th>
<th>Fond du Lac, WI</th>
<th>Stevens Point, WI</th>
<th>Glenbard, IL</th>
<th>KRMA, IL</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂S (ppmᵥ)</td>
<td>6,100</td>
<td>2,400</td>
<td>800</td>
<td>302</td>
<td>2,800</td>
</tr>
<tr>
<td>Siloxanes (µg/BTU)</td>
<td>1.6</td>
<td>2.4</td>
<td>1.3</td>
<td>0.6</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Cogeneration Thresholds:**

- **H₂S:**  
  - < 500 ppm preferred
  - < 1,000 ppm for some equipment

- **Siloxanes:** ~ 0.1 – 0.6 µg/BTU
Case Study Locations

Fond du Lac, WI
Dubuque, IA
Kankakee River Metropolitan Agency (KRMA), IL
Fond du Lac WPCP - Background

- New WPCP in 2008
  - 9.84 mgd & 21,600 lb BOD/day
  - Converted from Zimpro to Anaerobic Digestion (TPAD)
  - Construction costs = $57 million
  - Project did not include cogeneration
Fond du Lac TPAD System

- 4 Digesters Constructed: 2 thermophilic, 2 mesophilic

- Conservative design to accept high-strength industrial wastes.

- Cogeneration was not included; City elected to measure biogas quantity and quality for ~2 years before starting design.
Determine Facility Electrical Requirements

![Graph showing electrical usage over the months of 2008. The graph includes average on-peak and off-peak use, as well as total average usage.]
Biogas Use and Production

![Graph showing Biogas Use and Production](image)

- **Gas Usage to Heat AD and Bldgs using Boilers**
- **Biogas Production**

![Bar chart with months on the x-axis and mBTU/day on the y-axis](image)

- Chart data represents the daily biogas production and usage for each month from January to December.

**Graph Details**
- The y-axis is marked in mBTU/day, ranging from 0 to 100 mBTU/day.
- The x-axis shows the months from January (J) to December (D).

**Key Points**
- **Highest Production:** January
- **Lowest Production:** July

**Legend**
- **Green Bars:** Gas Usage to Heat AD and Bldgs using Boilers
- **Red Line:** Biogas Production
Fond du Lac - Cogen Design

- 130,000 ft³/day from sludge digestion
- 60,000 ft³/day from high-strength wastes
- New silo and pumping system for high-strength wastes
Heat is recovered from the engine jacket water and exhaust.

Can burn digester gas or natural gas to shave peak electric demand.

450 kW unit selected (CAT).

~50% turn down ability.
Fond du Lac Digester Gas Quality

- **Siloxanes:**
  - Siloxane build-up in boilers became an issue
  - 2.4 µg/BTU measured in gas
  - Threshold ~ 0.1 – 0.6 µg/BTU
  - Siloxane removal required

- **Hydrogen Sulfide:**
  - Industry/dairies
  - 2,340 ppmv measured in gas
  - Threshold ~ 500 – 1,000 ppmv
  - H₂S removal required

- **Moisture** – very high; typical of thermophilic biogas
Fond du Lac – Gas Conditioning

Biogas → Biological Scrubber
Hydrogen Sulfide Removal → Compression; moisture removal/drying → GAC Filter
Siloxane Removal → To Genset
## Fond du Lac – Costs and Financials

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value without High-Strength Wastes (current conditions)</th>
<th>Value with High-Strength Wastes (future conditions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Capital Cost</td>
<td>$3,173,000</td>
<td>$3,363,500</td>
</tr>
<tr>
<td>Energy Recovery Costs*</td>
<td>$1,854,000</td>
<td>$2,044,500</td>
</tr>
<tr>
<td>Annual Savings</td>
<td>$188,000</td>
<td>$248,000</td>
</tr>
<tr>
<td>Direct Payback</td>
<td>9.9 yrs</td>
<td>8.2 yrs</td>
</tr>
<tr>
<td>Estimated ROI (20 year)</td>
<td>9.1%</td>
<td>17.8%</td>
</tr>
</tbody>
</table>

*Biogas cleaning was also required for boiler-only option.*
Kankakee River Metropolitan Agency (KRMA)

- Service Population: 75,000
- Design Avg. Flow: 25 mgd
- Design Peak Flow: 85 mgd
- BOD Load: 40,000 lb/d
Existing KRMA Biogas Utilization

- Conventional anaerobic digestion with COGEN since 1986
- Two 250-kW Waukesha engine generators
- Hot water heat recovery to process and building heat
- No biogas conditioning
KRMA Cogen Design

- 220,000 ft³/day of biogas from sludge digestion
- No receiving facilities for high-strength wastes
- 450 kW unit selected (CAT)
KRMA Digester Gas Evaluation

- Sulfur compounds exceeded permissible concentration
  - Measured 2,800 ppm v vs 1,000 ppm v, allowed
  - H₂S removal required

- Siloxane concentrations:
  - Measured at ~0.2 µg/BTU vs. allowable 0.1 – 0.6 µg/BTU
  - Siloxane removal not required
KRMA – Gas Conditioning

Biogas → Biological Scrubber → Moisture removal → To Genset

Benefits:
• Bio-H$_2$S Removal has low O&M costs
• No siloxane removal = additional O&M cost savings
### KRMA – Costs and Financials

<table>
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<tr>
<th>Parameter</th>
<th>Value without High-Strength Wastes (current conditions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Capital Cost</td>
<td>$1,724,000</td>
</tr>
<tr>
<td>Annual Savings</td>
<td>&gt; $175,000</td>
</tr>
<tr>
<td>Direct Payback</td>
<td>&lt; 10 yrs</td>
</tr>
</tbody>
</table>
City of Dubuque

- Service Population: 68,000
- Design Avg. Flow: 10.9 mgd
- Design Peak Flow: 41 mgd
- BOD Load: 37,000 lb/d
Dubuque Operations - Background

- Raw sludge dewatering and incineration since the 1960s
- Fluid bed incinerators operating well beyond their useful life
- Facilities planning resulted in new direction - conversion to anaerobic digestion with land application of biosolids
Major Project

- Design 2009; Construction 2010 - 2013
  - Bid costs = $50 million
  - Major portion is biosolids digestion
  - Project did not include cogeneration, but did include biogas cleaning for boiler use
Dubuque Biogas Projections

- **Current Conditions:** 165,000 ft³/day
  ~ 390 kW

- **Future Design:** 303,000 ft³/day
  ~ 715 kW

- **Future Design w/ High-Strength:** 380,000 ft³/day
  ~ 900 kW
Dubuque – High-Strength Wastes

• Facility constructed to receive and screen septage and trucked in liquid wastes

• Additional facilities planned to accept high-solids food residuals

• Hauled materials can be pumped directly to digesters, sludge storage, or the head of the plant
Dubuque – COGEN Analyses

- Compared multiple types of engine generators with Capstone microturbines (MTs)
Dubuque – COGEN Analyses

- Capstone MTs selected because of:
  - Modularity for increasing capacity
  - Available building space better fit for MTs
  - Local Capstone service available in Dubuque
  - Costs and financials were similar to ICEs, mainly because gas cleaning was already included
Dubuque – COGEN Design

- Initial Installation: 400 kW
- Future Build-Out: 1,000 kW (increments of 200 kW)
Dubuque Digester Gas Evaluation

- Biogas cleaning installed as part of major (current) project for boiler use

- No Gas to Evaluate!

- $\text{H}_2\text{S}$ projections based on influent sulfate data, understanding of local industries, etc.

- Siloxane removal assumed to be required
Dubuque – Gas Conditioning

Biogas

Sulfa-Treat Media
H₂S Removal

Compression; moisture removal/drying

GAC Filter
Siloxane Removal

High Compression Skid
Heat Exchanger

To MTs
Dubuque – Costs and Financials

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (current conditions)</th>
<th>Value (future conditions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Capital Cost</td>
<td>$1,921,000</td>
<td>$2,700,000</td>
</tr>
<tr>
<td>Annual O&amp;M</td>
<td>$87,000</td>
<td>$150,000</td>
</tr>
<tr>
<td>Annual Electricity Value</td>
<td>($223,000)</td>
<td>($450,000)</td>
</tr>
<tr>
<td>Annual Savings</td>
<td>$136,000</td>
<td>$300,000</td>
</tr>
<tr>
<td>Direct Payback</td>
<td>14 years</td>
<td>9 years</td>
</tr>
<tr>
<td>Return on Investment (20 yrs)</td>
<td>3.6%</td>
<td>9.2%</td>
</tr>
</tbody>
</table>

*Dubuque will likely receive 20% grant for the project, which is not reflected in the analyses above.*
Lessons Learned

- Biogas quality drives economics:
  - Capital costs
  - O&M costs

- Supplemental feed stocks help, but be careful.

- The energy balance is the key!
  - Waste heat recovery from cogen should meet process and some building heating demands.

- Air permitting is becoming a big issue, and has been a big issue in some states for years.
Questions & Thank You!

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