CSWEA - Wisconsin Section Operations & Resource Recovery Committee

Digester Gas End-Use Opportunities Today’s Resource Recovery Facilities

Resource Recovery Seminar

November 14, 2018
Presentation Content

1. Options for Digester Gas End-Use
2. Renewable Fuel Standard (RINs) and Other Renewable Natural Gas (RNG) Markets
3. Financial Evaluations
4. Example Projects and Analyses
Options for Digester Gas End-Use

1. Do nothing - flare
2. Use for process/building heat
3. Combined heat and power (cogeneration)
4. Produce pipeline quality natural gas
5. Produce vehicle fuel (bioCNG, rCNG)
Status of Cogeneration

- Very common; use has grown in last 10-15 years
- Energy recovery efficiency has improved considerably
  - Electrical conversion 35-43%
  - Heat conversion 45-50%
  - Total efficiency > 85%

But
Status of Cogeneration

- High efficiency requires better gas quality & higher cleaning costs
- Overall maintenance costs are significant
- Few “green electricity” incentives and grant opportunities**
# Cogeneration O&M Costs

<table>
<thead>
<tr>
<th></th>
<th>Plant 1</th>
<th>Plant 2</th>
<th>Plant 3</th>
<th>Plant 4</th>
<th>Plant 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gas Cleaning</strong></td>
<td>Bio-H2S GAC-Silox</td>
<td>Chem-H2S GAC-Silox</td>
<td>Chem-H2S GAC-Silox</td>
<td>None</td>
<td>None</td>
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<tr>
<td><strong>Engine Size</strong></td>
<td>450 kW IC</td>
<td>180 kW IC</td>
<td>600 kW MT</td>
<td>2@750 kW IC</td>
<td>3@150-300 kW IC</td>
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</table>

**Cost Per kWH Produced ($/kWH)**

<table>
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<th>Plant 4</th>
<th>Plant 5</th>
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<tbody>
<tr>
<td>Gas Cleaning</td>
<td>$0.005</td>
<td>$0.008</td>
<td>$0.008</td>
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<tr>
<td>Engine Maint.</td>
<td>$0.012</td>
<td>$0.017</td>
<td>$0.017</td>
<td>$0.030</td>
<td>$0.090</td>
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<tr>
<td>Total</td>
<td>$0.017</td>
<td>$0.025</td>
<td>$0.025</td>
<td>$0.030</td>
<td>$0.090</td>
</tr>
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</table>

+ Labor!
When Does COGEN Make Sense?

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cogen</th>
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<tbody>
<tr>
<td>Electrical Cost &gt; $0.06/kWH</td>
<td>✔️</td>
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<tr>
<td>You Can Use All the Elec. On-Site</td>
<td>✔️</td>
</tr>
<tr>
<td>Relatively Clean Gas</td>
<td>✔️</td>
</tr>
<tr>
<td>Year Round Need for Heat</td>
<td>✔️</td>
</tr>
<tr>
<td>You Love Maintaining Things</td>
<td>✔️</td>
</tr>
<tr>
<td>You Have No Better Options and Want to Be “Green”</td>
<td>✔️</td>
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</table>
Cogeneration – Potential For Electrical RINs
Renewable Fuel Standard (RFS) Program

- 2007 – Congress indicated renewably generated electricity should be pathway under the RFS.
- 2014 - EPA approved an electricity pathway for the RFS program.
- 2018 - EPA still has not acted on this approval by processing formal applications from renewable electricity producers.
- EPA has indicated the agency needs to resolve policy issues regarding how the RFS ‘electric pathway’ program will function; nothing will be done until that is resolved.
<table>
<thead>
<tr>
<th></th>
<th>Cogen</th>
<th>Pipeline RNG</th>
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</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>?</td>
<td>⭐️</td>
</tr>
<tr>
<td>Overall O&amp;M Cost</td>
<td>⭐️</td>
<td>⭐️</td>
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<tr>
<td>Value of Gas</td>
<td>⭐️</td>
<td>⭐️</td>
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<tr>
<td>Payback/ROI</td>
<td>⭐️</td>
<td>⭐️</td>
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<tr>
<td>Market Concerns/Unknowns</td>
<td>⭐️</td>
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</table>
RNG Production
Carbon Dioxide Removal Replaces Engine Generator

1. Membrane Separation
2. Pressure Swing Adsorption
3. Water Scrubbing
4. Amine Scrubbing - New to US market, more common technology in Europe
Renewable Fuel Standard (RFS)

- Congress created the RFS program to reduce greenhouse gas emissions and expand the nation’s renewable fuels sector.

GHG Emission Reduction is the Key to Renewable Fuel Designation and Value Under the RFS

D5 fuels - 50% lifecycle GHG emission reductions
- RNG from High-Strength Waste

D3 fuels - 60% lifecycle GHG emission reductions
- POTW biogas
- Landfills
Congress Sets Renewable Volume Targets Based on EPA Recommendations

Congressional Volume Target for Renewable Fuel

36 Billion Gallons of Renewable Fuel by 2022

Key:
- Cellulosic (D-3)
- Advanced (D-5)
- Biodiesel (D-4)
- Renewable (D-6)

~16 bgal/yr (D3)
~4 bgal/yr (D5)
~16 bgal/yr (D6/D4)
D3 Quantities Have Not Met Targets

Shortage of D3 production has created higher demand, even though EPA has lowered targets.
Renewable Identification Numbers (RINs)

- RINs are “credits” used for compliance and are the “currency” of the RFS program

- Renewable fuel producers generate RINs (e.g., WWTPs)

- Obligated parties obtain and then ultimately retire RINs for compliance with the RFS program
RIN Life Cycle

Fuel production and fuel use "locations" are not necessarily connected

Source: USEPA
In 2014, RFS rule amendments designated CNG and LNG from landfill gas and certain types of digesters as cellulosic biofuel that qualifies for D3 RIN generation.

This changed everything for WWTPs and Landfills!
Status of Renewable Natural Gas (RNG)

- Significant interest; only a handful of actual WWTP installations:
  - City of San Antonio, TX
  - City of Grand Junction, CO
  - City of San Mateo, CA
  - King County WWTP, Seattle, WA
  - City of Dubuque, IA
  - Des Moines WRA, IA
  - City of Sioux City, IA

- Dane County, WI – Landfill and Ag Digesters
- Kewaunee/Brown County – Ag Digester (WE Energies)
Markets for RNG

- **Renewable Fuel Standard (RFS) Markets:**
  - Non-renewable fuel developers are required to produce renewable fuels or purchase RINs
  - POTW digester gas converted to RNG - D3 RINs and/or D5 RINs
  - California market (LCFS) adds significant value but may be difficult to qualify

- **Other Markets**
  - RE100 – Large companies committed to 100% renewable energy, working to increase demand for renewable energy.
  - Provide long-term guaranteed contracts (15-25 years)
  - Lower value than RFS D3, but lower risk as well
Historical RFS RIN Values

Max D3 ~ $3.10/RIN

Max D5 ~ $1.10/RIN

Current D3 ~ $1.95 (down 37%)

Current D5 ~ $0.32 (down 70%)
D3 and D5 RIN Values for Digester Gas

- 11.73 RINs per MMBTU of CNG or LNG
- @ 600 BTU/ft$^3$ biogas = 0.007 RINs/ft$^3$ biogas
- ~ 700 RINs per 100,000 ft$^3$ biogas

- D3 RIN @ $2.00/RIN
  - ~ $1,400 per 100,000 ft$^3$ biogas
  - ~ $24/MMBTU (vs. $36/MMBTU 12 mos. ago)

- D5 RIN @$0.35/RIN
  - ~ $250 per 100,000 ft$^3$ biogas
  - ~$4/MMBTU (vs. $12/MMBTU 12 mos. ago)
California’s Low Carbon Fuel Standard (LCFS) Can Add Significant Value to RNG Sold in California

- Value is based on holistic life cycle GHG emission reduction
- Ag digester gas has extremely high value
- D3 RNG from POTWs likely has limited long-term value unless program continues to expand
- D5 RNG has little chance to be sold for LCSF credits.
California LCFS Program Drivers

- Ag digester construction
  - Significant grant funding available
  - Extremely low Carbon Intensity (CI) scores = $$$$ 
  - Displacing other RNG that has less value (higher CI scores)
LCFS revenue is additive to RIN revenue if the RNG is sold to qualified California end-users.
RFS Markets - RNG Values from POTWs

~$19/MMBTU
~$39/MMBTU

California LCFS Program is Very Competitive
WWTP Gas: Current vs. Potential Value

Gas Value Per Million BTUs

- Heating Fuel: $3.00
- COGEN Fuel: $8.00
- D5 Trans Fuel: $7.00
- D5 + LCFS: $19.00
- D3 Trans Fuel: $27.00
- D3 + LCFS: $39.00

25% Other Renewable Markets

75% Pipeline Quality Gas

RFS Program
City of Dubuque

- 11 mgd DAF WWTP
- New temperature phased anaerobic digestion (2013)
- 2014 cogeneration startup (microturbines)
- Significant co-digestion of high-strength wastes
- H$_2$S and siloxane removal already installed
Dubuque Gas Conditioning
Dubuque Cogeneration with Microturbines

Microturbines
3 @ 200 kW = 600 kW

Heat Recovery
Dubuque Pipeline Quality Gas Project

- Third party RNG developer is at risk; rights to all digester gas
- 15-year term + option for 5 years
- Use existing gas conditioning system/facilities (moisture, H₂S, and siloxane removal)
- PSA to remove carbon dioxide; inject into utility pipeline
- Developer believed all RINs are D3 [caution]
Dubuque Pipeline Quality Gas Project

- Third party provider will provide to the City:
  - Percentage of gross revenue – RINs and Gas Sales
  - Pipeline natural gas for cogen and facility use
  - Lease payment
  - Operational costs above current (electricity, gas cleaning media, labor, etc.)
Dubuque Pipeline Quality Gas Project
PSA System for CO$_2$ Removal (Dubuque)
Estimated Gross Revenue to 3rd Party

- Digester Gas Production: 250,000 ft³/day
- Energy Value: 150 MMBTU/day
- Gas Sales ($3/MMBTU): $450/day
- D3 RINs: 1,800 RINs/day
- RIN Value ($3/RIN): $5,400/day
- LCFS Credits: $1,000/day
- Gross Sales: $2.5 million/yr

Actual Values
- D5 RINs ($0.35/RIN): $630/day
- $0/day
- $0.4 million/yr
Anticipated Benefits to Dubuque

Total Value: $180,000/yr

- No upfront capital and no additional O&M costs to City
- Improved microturbine life
- Ability to add 4\textsuperscript{th} and 5\textsuperscript{th} microturbine if successful
- Bond/agreement to make the City whole if system is discontinued

Actual Value
$20,000/year
Dubuque Project Status

- Start-up late March 2018
- Long delay getting system installed and approved
- Third party was not accustomed to working in the municipal WWTP realm
- Working with City to reconfigure digester feeding
  - D3 from sludge biogas
  - D5 (or other) from HSW biogas
Midwest WWTP – 25 mgd DAF Pipeline Quality Gas Evaluation

- Gas production ~ 280,000 ft³/day
- All D3 RINs by definition
- Currently no digester gas use except for process heat
- Low electrical costs ~ $0.05/kWH (cogen not considered)
- Requires H₂S, moisture, siloxane and CO₂ removal
  - Utilize membrane CO₂ removal system
# Project Costs and Revenue

<table>
<thead>
<tr>
<th></th>
<th>Continue with Boilers</th>
<th>Produce RNG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
<td>$0</td>
<td>$6,100,000</td>
</tr>
<tr>
<td><strong>Gas Conditioning O&amp;M</strong></td>
<td>$0</td>
<td>$340,000/yr</td>
</tr>
<tr>
<td><strong>Relative Power</strong></td>
<td>$0</td>
<td>$120,000/yr</td>
</tr>
<tr>
<td><strong>D3 RIN (80% of total)</strong></td>
<td>$0</td>
<td>($1,300,000/yr)</td>
</tr>
<tr>
<td><strong>Boiler Maintenance</strong></td>
<td>$20,000/yr</td>
<td>$20,000/yr</td>
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<tr>
<td><strong>Annual Cost (Revenue)</strong></td>
<td>$20,000</td>
<td>($820,000)</td>
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<tr>
<td><strong>Opinion of 20-Yr Present Worth</strong></td>
<td>$300,000</td>
<td>($8,430,000)</td>
</tr>
<tr>
<td><strong>Direct Payback</strong></td>
<td>NA</td>
<td>~7-8 years*</td>
</tr>
</tbody>
</table>

Payback was < 5 years only 8 months ago
Anaerobic Lagoon Application

- City owned lagoon treating meat processing wastewater
- >800,000 ft³/day biogas (all D5 RINs)
- Low electrical costs ($0.04-$0.05/kWH)
- Third party currently has gas rights (similar to Dubuque)
- Value of gas has continued to decrease
- Evaluate options
Lagoon Biogas Conditioning Upgrades

• Requires H₂S, siloxane, and moisture removal
• Add CO₂ removal
  - Concerns with O₂ and N₂ from lagoon gas collection
  - Membranes and amine systems not able to remove O₂/N₂
  - Two-stage PSA (O₂ > 1%)
  - Single-stage PSA with de-oxygenation system (O₂ < 0.8%)
# Pipeline Gas Specs

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>BTU Content</td>
<td>&gt; 950 BTUs per ft³</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>&lt; 3% by volume</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>&lt; 4% by volume</td>
</tr>
<tr>
<td>Total Inerts (N₂ + CO₂)</td>
<td>&lt; 5% by volume</td>
</tr>
<tr>
<td>Oxygen</td>
<td>&lt; 0.3% by volume</td>
</tr>
<tr>
<td>Water</td>
<td>&lt; 5 lb/mmscf</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>&lt; 8 ppm</td>
</tr>
<tr>
<td>Total Sulfur</td>
<td>&lt; 16 ppm</td>
</tr>
<tr>
<td>VOCs</td>
<td>&lt; current pipeline levels</td>
</tr>
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</table>
Lagoon Gas: Current vs. Potential Value

Gas Value Per Million BTUs

- 3rd Party Sale: $0.10
- Heating Fuel: $3.00
- COGEN Trans Fuel: $5.00
- D5 Trans Fuel: $7.00
- D5 + LCFS: $19.00
- D3 Trans Fuel: $27.00
- D3 + LCFS: $39.00

Other Renewable Markets: $8-$15
# Preliminary Lagoon Biogas Valuation (2017)

**Date:** September 5, 2017  
**Biogas Financial Analysis:** City of Waterloo

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>MSW/Industrial</th>
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</thead>
<tbody>
<tr>
<td>RNG Energy Content (MMBTU)</td>
<td>150,000</td>
</tr>
<tr>
<td>RNG Utilization</td>
<td>100% Transportation Fuel</td>
</tr>
<tr>
<td>Carbon Intensity Value (gCO2e/MJ)</td>
<td>30</td>
</tr>
<tr>
<td>LCFS Credits Generated (MT/yr.)</td>
<td>10,438</td>
</tr>
<tr>
<td>LCFS Credit Value ($/MT)</td>
<td>$85.00</td>
</tr>
<tr>
<td>RINs Generated (RIN/yr.)</td>
<td>1,759,050</td>
</tr>
<tr>
<td><strong>D5 RIN Value ($/RIN)</strong></td>
<td>$1.08</td>
</tr>
<tr>
<td>Value of Natural Gas ($/MMBTU)</td>
<td>$3.00</td>
</tr>
</tbody>
</table>

**Current RIN Market**

- $0 LCFS  
- $0.35/RIN

**Potential Annual Revenues**

- LCFS Credits: $887,000  
- RINS: $1,900,000  
- Gas Sales: $450,000  
- Total Potential Annual Revenues: $3,237,000
<table>
<thead>
<tr>
<th></th>
<th>2017 RFS (D5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
<td>$9,000,000</td>
</tr>
<tr>
<td><strong>Gas Conditioning O&amp;M</strong></td>
<td>$500,000/yr</td>
</tr>
<tr>
<td><strong>Relative Power</strong></td>
<td>$200,000/yr</td>
</tr>
<tr>
<td><strong>RNG Revenue (80% of total)</strong></td>
<td>($2,900,000/yr)</td>
</tr>
<tr>
<td><strong>Annual Cost (Revenue)</strong></td>
<td>($2,200,000)</td>
</tr>
<tr>
<td><strong>Direct Payback</strong></td>
<td>~4 years</td>
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# Lagoon Project Costs and Revenue

<table>
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<tr>
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<th>2017 RFS (D5)</th>
<th>2018 RFS (D5)</th>
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<td><strong>Capital Costs</strong></td>
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<td>$9,000,000</td>
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<tr>
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<td>$500,000/yr</td>
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<tr>
<td><strong>Relative Power</strong></td>
<td>$200,000/yr</td>
<td>$200,000/yr</td>
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<tr>
<td><strong>RNG Revenue (80% of total)</strong></td>
<td>($2,900,000/yr)</td>
<td>($840,000/yr)</td>
</tr>
<tr>
<td><strong>Annual Cost (Revenue)</strong></td>
<td>($2,200,000)</td>
<td>($140,000)</td>
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<tr>
<td><strong>Direct Payback</strong></td>
<td>~4 years</td>
<td>&gt;60 years</td>
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<tr>
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<td>2017 RFS (D5)</td>
<td>2018 RFS (D5)</td>
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<tr>
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<tr>
<td>Direct Payback</td>
<td>~4 years</td>
<td>&gt;60 years</td>
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</table>
Impact of RNG Values

<table>
<thead>
<tr>
<th>RNG Value ($/MMBTU)</th>
<th>Current D3 RIN</th>
<th>Current D5 RIN</th>
<th>RE100 Range</th>
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<tbody>
<tr>
<td>$0</td>
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<td>$6</td>
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<tr>
<td>$41</td>
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Closing Thoughts

- Digester gas end-use should consider RNG production in addition to cogeneration.

- Cogeneration is maintenance intensive.

- There are low-risk (and lower value) RNG opportunities available through turn-key providers and longer term guaranteed markets.

- RFS markets have and will fluctuate – it’s a market that will have its ups and downs.
Closing Thoughts

- Year 2022 is not a “sunset” year for the RFS program; the program will continue until/unless Congress decides to discontinue the program.

- eRINs could help drive renewed interest in cogeneration systems utilizing digester gas.

- California’s Low Carbon Fuel Standard program has recently expanded and has been authorized through 2030; may be difficult to access for POTWs.

- Other states are likely to follow California’s lead, though perhaps not as aggressively.