North American Meat Institute Biogas Upgrading

BIOFerm™ Energy Systems
January 29, 2018
Introduction

• Generating biogas
• Conditioning biogas
• Biogas sale incentives
• Economic examples
• End notes
Introduction
Sources of Feed Gas

Upgrade biogas to natural gas quality for pipeline injection or CNG from a variety of feedstocks:

- Process waters
- Paunch
- Litter
- DAF
- Centrifuge
- Hide rinses
Biogas generation & energy content

Example

• Paunch example:
  18,000 ton/year dewatered
  ~120cfm of biogas
  56-60% CH4 content
  30,000 MMBtu/year
  400 kW

• Process waters:
  ~1-1.5 MGD
  ~580cfm of biogas
  60-65% CH4 content
  210,000 MMBtu/year
  2,700 kW
Biogas generation
Example

- Poultry litter:
  71,000 ton/year
  ~720 cfm of biogas
  56-60% CH4 content
  218,000 MMBtu/year
  2,800 kW

- Assorted others:
Introduction – biogas upgrading

Process Overview

• Gas upgrading: A series of processes that purify a given gas stream by removing undesired components

• Components that are typically removed:
  – CO₂
  – H₂S
  – H₂O
  – N₂/O₂
  – NH₃
  – Siloxanes/VOC’s
# Introduction – biogas upgrading

## Methods

<table>
<thead>
<tr>
<th>METHOD</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSA (pressure swing adsorption)</td>
<td>Gases adsorbed onto molecular sieve material</td>
</tr>
<tr>
<td>Membrane separation</td>
<td>Selective permeation of gases at pressure through membrane materials</td>
</tr>
<tr>
<td>High pressure water scrubbing</td>
<td>Gases dissolved in high pressure water</td>
</tr>
<tr>
<td>Chemical absorption</td>
<td>Gases adsorbed by chemical solution</td>
</tr>
<tr>
<td>Cryogenic separation</td>
<td>Extreme low T for liquefaction &amp; separation of gases</td>
</tr>
</tbody>
</table>
Gas Upgrading Process
Carbotech PSA Model Block Diagram

- **Biogas**
  - Directly from digester or gas holder

- **Pre-cooling 70°F**
  - Reduce water content to avoid condensation during downstream compression

- **Compression 135 psig**
  - Compress gas to increase partial pressure of CO₂ / VOC for downstream removal

- **Drying 40°F**
  - Cool gas to condense water, oil and VOC and reduce adsorbent loading

- **VOC removal 70°F**
  - Remove VOC, HCFC and siloxane through activated carbon adsorption

- **VOC removal**
  - Single activated carbon bed or heat regenerated dual activated carbon bed
Gas Upgrading Process
Project example– Guymon, OK

Seaboard Foods
- 5.5 million hogs/year
- 1,200 cfm lagoon biogas
- 850 cfm, ~388,000 MMBtu/year product to pipeline
Driver – biogas upgrading
What are the incentives?

2007 EISA – Energy Independence & Security Act
- Reduce foreign oil dependence
- Reduce GHGs
- Promote green sector job growth in the US

RINs are generated **ONLY if:**
- Fuel is used for transport, heating oil or jet fuel
- Is produced under an EPA approved pathway
- The feedstock used to make the fuel is a **Renewable Biomass**
  - Products from planted crops/crops residue /trees/tree residue
  - **Animal waste material and byproducts**
  - Algae
  - Biomass cleared from areas/building to reduce wildfires
  - Separated yard or food waste

- 4 related annual renewable fuel mandates;
  - **Cellulosic biofuel**
  - Biomass based diesel
  - Advanced biofuel
  - Total renewable fuel
- Obligations imposed on diesel, gas refiners & imports
- RINs are the ‘currency’ of compliance – saleable regulatory credits representing a quantity of qualifying renewable fuel

**Renewable Identification Numbers, RINs**

**D3** – RNG, CNG: biogas from LFs, muni digesters, Ag digesters, etc. (cellulosics)

**D5** – RNG, CNG: biogas from waste digesters
Driver – biogas upgrading
What are the incentives?

California Low Carbon Fuel Standard (LCFS)
Oregon Clean Fuels Program
• Require 10% reduction in transportation fuel carbon intensity by 2020/2026 (reduce carbon pollution)
• CI, carbon intensity, measures GHG emissions associated with producing & consuming a fuel (gCO2e/MJ)
• Requires regulated parties, (refiners & importers of gasoline and diesel), to ensure that overall CI score for fuel pool meets annual CI target

LCFS credits are saleable regulatory credits
Each feedstock and end use application has a defined pathway and CI which generates LCFS credits
• Manure feedstock to RNG has ~ -100 to -400 gCO2/MJ
Economics – biogas pricing
What is possible

Gas pricing components:

- Brown gas - $2.50 to $3.00 /MMBtu
- RIN credit
  - D3 – $20 to $30 /MMBtu
  - D5 - $7 to 10 /MMBTU RIN value split with marketer/buyer & producer:
- LCFS credit - $30 to $40 /MMBtu
- 15-35% to buyer : 65-85% to producer (once dispensed & sold to obligated party)

<table>
<thead>
<tr>
<th>BROWN GAS</th>
<th>RIN</th>
<th>LCFS</th>
<th>TOTAL D3, manure</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2.50 to $3.00/MMBtu</td>
<td>$30.30/MMBtu</td>
<td>$37.52 to $39.20/MMBtu</td>
<td>~$70 to $73/MMBtu</td>
</tr>
</tbody>
</table>

RIN/LCFS cost information courtesy of Andy Dvoracek of Camco (prices as of Jan 26, 2018)
Economics – biogas pricing
What is achievable

Fixed price; $/MMBtu fixed for 5, 7, 10, 20 years….however,
• Much lower price compared to spot market
• Typically requires minimum delivery volume (LD’s)
• Typically includes regulatory outs
• Seller does not get a share of environmental credit but must certify output
• ‘easier’ to get financing

$8,$11,$16 /MMBtu
‘limited buyers’

Variable price:
• Seller can keep environmental credits
• Seller releases RNG to buyer/marketer, but earns greater portion of net margin
• Greater return, higher risk
• ‘harder’ to finance

$20,$30,$50+ /MMBtu
‘10-12 buyers’

Hybrid price structures:
• A base price for RNG and a portion of environmental credit
• In between risk
• ‘somewhat easier’ to get financing

$11,$16,$20 /MMBtu
‘10-12 buyers’
Economics – biogas pricing
Variability, uncertainty?

<table>
<thead>
<tr>
<th>LCFS</th>
<th>1/15/18 – 1/21/18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg $/MT</td>
<td>127.15</td>
</tr>
<tr>
<td>Price range $/MT</td>
<td>97.14-145.00</td>
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</tbody>
</table>

East Coast Refiner Blames RFS for Bankruptcy Filing...

This week, Philadelphia Energy Solutions, identified as the largest oil refinery along the U.S. East Coast, filed for bankruptcy protection. One of the reasons they cited for the filing was the costs required to comply with the Renewable Fuel Standard (RFS).

While the headlines focused on the RFS, the bankruptcy appears to be driven by several unrelated business reasons, including continued pressure on refining margins. The company's two refineries turn up to 335,000 barrels of crude oil into gasoline and other fuels. ......

Source ICF. ARB, RNG Coalition
## Biogas economics

### Examples

- **Process waters:**
  - ~1-1.5 MGD
  - ~580 cfm of biogas
  - 60-65% CH4 content
  - 210,000 MMBtu/year
  - 2,700 kW

<table>
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<tr>
<th></th>
<th>Natural gas displacement</th>
<th>Electric displacement</th>
<th>Gas upgrading to renewable natural gas (interconnect)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital cost</strong></td>
<td>Assumed in place</td>
<td>$3,780,000</td>
<td>$3,900,000</td>
</tr>
<tr>
<td><strong>Capital amortization, $/yr</strong></td>
<td></td>
<td>$753,024</td>
<td>$776,928</td>
</tr>
<tr>
<td><strong>Operating Cost, $/yr</strong></td>
<td>$50,000</td>
<td>$685,908</td>
<td>$275,000</td>
</tr>
<tr>
<td><strong>Total cost, $/yr</strong></td>
<td>$50,000</td>
<td>$1,438,832</td>
<td>$1,681,928</td>
</tr>
<tr>
<td><strong>Gas value $/yr</strong></td>
<td>$630,000</td>
<td>$1,512,000</td>
<td>$1,995,000</td>
</tr>
<tr>
<td><strong>Net value, $/yr</strong></td>
<td>$580,000</td>
<td>$73,068</td>
<td>$943,072</td>
</tr>
</tbody>
</table>

Note: Electric assumed $0.07/kWh, Natural gas $3/MMBtu, Amortization – 100% debt, 10% int, 7 yr term
Biogas economics

Examples

- Paunch:

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<th>Paunch removal, Natural gas displacement</th>
<th>Gas upgrading to renewable natural gas</th>
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<tbody>
<tr>
<td>Capital cost</td>
<td>Assumed in place</td>
<td>$8,500,000</td>
</tr>
<tr>
<td>Capital amortization, $</td>
<td></td>
<td>$1,693,320</td>
</tr>
<tr>
<td>Operating Cost, $/yr</td>
<td>$284,000</td>
<td>$623,000</td>
</tr>
<tr>
<td>Total cost, $/yr</td>
<td>$284,000</td>
<td>$2,446,320</td>
</tr>
<tr>
<td>Gas value $/yr</td>
<td>$630,000</td>
<td>$3,000,000, D3/D5=$12.50</td>
</tr>
<tr>
<td>Net value, $/yr</td>
<td>$346,000</td>
<td>$825,680*</td>
</tr>
</tbody>
</table>

Note: Electric assumed $0.07/kWh, Natural gas $3.00/MMBtu, Paunch $13/ton removal, Amortization – 100% debt, 10% int, 7 yr term

* - includes 50% of the paunch removal cost as revenue
Biogas economics
To do or not to do

• Debt deals few and far between
• Equity – investors with higher risk appetite
• Backend byproduct interests
• Compliance assurance – conversion of certain streams
• Green portfolios
Biogas economics
Backend - Not to be forgotten

- Paunch:

  18,000 ton/year dewatered
  ~120 cfm of biogas
  56-60% CH4 content
  30,000 MMBtu/year
  400 kW
THANK YOU FOR YOUR ATTENTION!

Christine McKiernan
References

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