Landfill Gas to CNG 101
Basics of LFG Conversion to B-CNG and B-CNG Utilization

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B-CNG Feedstocks

- Landfill gas
- WWTP digester gas
- Other digester gases
- Common concerns
  - Moisture
  - High CO₂
  - H₂S
  - VOCs
Landfill Gas as a B-CNG Feedstock

• Characteristics are landfill-specific
  – CH$_4$ = 45% to 55%
  – CO$_2$ = 36% to 44%
  – N$_2$ = 17% to 1%
  – O$_2$ = 2% to Nil
  – Saturated with moisture
  – H$_2$S = 25 ppmv to 1,000 ppmv+
  – VOCs are variable
California Air Resources Board (CARB) Primary Standards for CNG

- Methane $\geq$ 88%
- Oxygen $\leq$ 1%
- Carbon dioxide + nitrogen $\leq$ 4.5%
- For LFG, the $\text{CO}_2 + \text{N}_2 + \text{O}_2$ will require $\text{CH}_4$ to be above 95%
- Dew point of 10° F below ASHRE 99% low temperature for region
CARB Secondary Standards for CNG

- Ethane (C2) ≤ 6% (60,000 ppmv)
- C3 and higher ≤ 3%
- C6 and higher ≤ 0.2%
- Sulfur ≤ 16 ppmv
- CARB does not identify siloxane as a compound of concern, but as an industry, we recognize that it is a cause for concern
Cummins Westport Natural Gas Engine Standards

- Btu/lbm (LHV) $\geq$ 16,000
- H$_2$S $\leq$ 6 ppmv
- Siloxanes $\leq$ 3 ppmv
- Methane number $\geq$ 65
- 16,000 Btu/lbm (LHV) $\sim$ 85% CH$_4$
Acceptable Landfill Gas Characteristics

• CO₂ removal is employed to increase CH₄ content of the landfill gas. An end point CO₂ of 2% is a comfortable target.

• Typical worst case acceptable B-CNG product would be:
  – CH₄ = 85.0%
  – CO₂ = 2.0%
  – N₂ = 12.5%
  – O₂ = 0.5%
Acceptable Landfill Gas Characteristics (cont…)

• Equivalent landfill gas for this product would be:
  – CH₄ = 50.8%
  – CO₂ = 40.6%
  – N₂ = 7.8%
  – O₂ = 0.8%

• Nitrogen concentrates by a factor of about 1.6 during processing
Alternatives for CO$_2$ Removal

- Membrane separation
- Pressure swing adsorption
- Selexol
- All rely on the differences in the physical properties of CH$_4$ versus CO$_2$
Typical B-CNG Membrane Plant
Sonoma County

- 100 scfm inlet
- Dedicated wells to reduce nitrogen level
- Low cost membrane configuration
  - Low pressure (100 psig versus conventional 150-170 psig)
  - Single-stage membrane
  - Both of above reduced methane recovery
  - Richer waste gas was returned to main wellfield for use in engine plant
Basis of Design (cont…)

- CNG delivery pressure 3,600 psig
- Slow fill system. No storage.
- Product gas = 40 scfm
Plant Components

- Centrifugal blower
- Air-to-gas cooler
- Chilled water to LFG heat exchanger (40º F)
- Reheat heat exchanger (LFG-to-LFG)
- Sliding vane type compressor (110 psig)
- Two in series activated carbon vessels
- Particulate filter
- Single-stage membrane
Plant Components (cont…)

- Odorization
- Three-stage reciprocating compressor (100 psig to 3,600 psig)
- Two-nozzle fill post for CNG dispensing
- SCADA
- Equipment, except for activated carbon vessels, are in a container
## Typical Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw LFG</th>
<th>Product Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>54.7%</td>
<td>92.0%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>40.7%</td>
<td>1.4%</td>
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<tr>
<td>Nitrogen</td>
<td>3.9%</td>
<td>6.2%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.7%</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

% Methane Recovery = 63%
Typical B-CNG Pressure Swing Adsorption Plant Basis of Design

- 75 scfm inlet (Guild standard module)
- Product gas = 40 scfm
- Percentage methane recovery ~ 90%
- Product gas pressure = 90 psig
Plant Components

- Centrifugal blower
- Air-to-gas cooler
- Chilled water to LFG heat exchanger (60º F)
- Feed compressor
- Air-to-gas cooler
- PSA vessels
- Vacuum pump
- Surge vessels
- Odorization
- Reciprocating compressor (100 psig to 3,600 psig)
- Slow fill CNG dispensers
## Typical Performance

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<tr>
<th>Parameter</th>
<th>Raw LFG</th>
<th>Product Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>51.5%</td>
<td>85.5%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>41.1%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>6.9%</td>
<td>11.6%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.5%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

Note: Inlet N₂ set at maximum acceptable level to yield a product gas CH₄ level acceptable to Cummins Westport
Rough Conversion Factors
LFG to Liquid Fuel

- Low CH\textsubscript{4} recovery configuration (65% recovery)
  - 100 scfm LFG = 406 GDE per day
  - 100 scfm LFG = 429 GGE per day

- High CH\textsubscript{4} recovery configuration (90% recovery)
  - 100 scfm LFG = 561 GDE per day
  - 100 scfm LFG = 594 GGE per day

Note: LFG at 55% CH\textsubscript{4}
Slow Fill Versus Fast Fill

- Slow fill requires no storage, only compression to pressure required by vehicles (typically 3,600 psig).
- Vehicles can only be filled at the rate of the capacity of the plant (e.g., 100 scfm).
- Operation of the plant is likely to be at least somewhat intermittent.
- Fast fill requires storage, (typically at 5,000 psig) in above-ground ASME code vessels.
- A typical storage arrangement would employ three 20-inch diameter x 23-foot long tubes, each holding 10,000 scf.
Slow Fill Versus Fast Fill (cont…) 

- About 12,000 scf of the total volume stored is available for fueling, which is equal to about 100 GGE
Conclusions

• Conversion of biogas to B-CNG has been proven to be technically feasible

• B-CNG’s raw landfill gas specification is more forgiving than pipeline quality gas plant specifications

• Economics are very project-specific. In general, B-CNG is:
  – More expensive than CNG (without grants and incentives)
  – Less expensive than liquid fuels