Tapping into the Transportation Fuel Market

Global Methane Initiative
March 15th, 2013
Vancouver, BC
Greenlane started as Flotech, which was founded 1986 in New Zealand to provide machinery installation services to the compressed natural gas industry.

Greenlane is the global leader in the biogas upgrading market, with ~70 installations in 15 countries. The company uses a water scrubbing and pressure/temperature adsorption gas cleaning process to produce renewable natural gas (RNG) from biogas and landfill gas.

The organization operates internationally, offering solutions for:

- Gas Purification, Drying and Conditioning
- Industrial Heat Exchange
- Gas Compression
- Technical Support, Field Services and Spare Parts
Biogas Upgrading
BIOGAS requires upgrading to be used as CNG or LNG Vehicle Fuel
Biogas is produced by the anaerobic digestion of organic matter such as manure, sewage sludge, industrial waste, the organic fractions of household waste, etc.

Biogas can be upgraded to be a substitute for natural gas.

The typical gas composition of biogas and biomethane are as follows:

**Biogas**
- CH$_4$: ~60%
- CO$_2$: ~39%
- N$_2$+O$_2$: <1%
- H$_2$S: 50 - 5000 ppm
- H$_2$O: Saturated
- Siloxanes: Trace

**Biomethane**
- CH$_4$: >96%
- CO$_2$: ~1%
- O$_2$: <0.4%
- Total inerts: <4%
- H$_2$S: <1 ppm
- H$_2$O: <1 ppm
- Siloxanes: <1 ppm
Equivalent Units of Energy - 1 Million Btu’s

Gallons of Diesel Fuel (@ 139,000 btu/gal) – 7.2 gallons

Gallons of Gasoline (@ 125,000 btu/gal)

Natural Gas at Ambient Pressure – 1000 SCF (1 atmosphere, 14.7 psia)

Compressed Natural Gas in a Vehicle (3500 psi) – 1000 SCF (238 atmospheres pressure)

LNG at -260 F (666 SCF gas/ CF LNG) – 1.5 ft³ (12 gallons)

8 Gallons

(8 x 8 x 16 minibus)

1000 ft³

4.2 ft³ (31 gallons)

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Distance Travelled on $10 of Fuel (assuming 25 MPG)

- At $4 per gallon of diesel (2.5 gal) = 63 miles
- At $3.50 per gallon of gasoline (2.8 gal) = 71 miles
- At $5 per MM Btu of Natural Gas (at $0.65 per GGE)* = 7.7 GGE = 192 miles

*$/Gal of gas equivalent (GGE) = ($5/MMBTU) X (0.13 MMBTU/Gal of gas)
Biogas Drying

- Biogas needs to be dried for most applications
- Systems may use more than one step in combination
- The sequence of steps are often chosen depending on what steps are used to process the biogas. It may be ideal for the gas to be hot or cold.

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**H₂S Removal – Iron Sponge**

- Removes sulfides
- Iron sponge generally refers to wood chips impregnated with iron oxide
- Downflow gas through packed bed of iron sponge
- Iron oxide (Fe₂O₃) reacts with sulfides (H₂S) to produce iron sulfide (Fe₂S₃) and water (H₂O): 2 Fe₂O₃(s) + 6 H₂S(g) → 2 Fe₂S₃(s) + 6 H₂O(l)
- Must drain excess water occasionally so as not to flood the bed
- Bed can be regenerated several times before needing replacement

[Diagram of H₂S removal process]

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H$_2$S Removal - Biofiltration

- Removes sulfides (and commonly used for odor control)
- Uses microbes living on a support matrix to remove sulfides
- Microbes oxidize reduced sulfur compounds to sulfate
- Sulfides absorb into a liquid film and are then metabolized by the microbial cells

Occurs in:
- Above grade packed towers
- Below grade systems filled with natural media like wood chips or peat moss.

**Biotrickling Filter**

[Diagram of biotrickling filter system]

**Fig. 5. Systems for removal of H$_2$S: (a) bioscrubber; (b) biofilter; (c) biotrickling filter.**

[Source: www.americanbiogascouncil.org]
Biogas → Humidity Control → Sulfide & Siloxane Removal → CO₂ Removal → Compression & Offtake

- Biogas → Dryer → Chiller → Dry Gas
- Sulfide 20 - 200 ppm → Biofiltration → Iron Sponge → Sulfatreat → Activated Carbon → Silica Gel → Medium BTU Biogas
- Water Wash → Amine Scrubber
- Membrane → Cryogenic → PSA
- Tube Trailers (4000 psi)
- Gas Grid Injection (50-1000 psi)
- Vehicles (3500 Psi)
- To on site Power Generation Or Direct use

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A Simple Concept

- Biogas is primarily methane (CH₄) and carbon dioxide (CO₂)

- Water under pressure can be used to separate these two gases through their different solubility in H₂O
Water Regeneration

- Water from the scrubber is sent to flash tank to depressurize, so the small amount of absorbed methane can be removed from the water

- The water is then sent to a stripper that removes the gases absorbed in the water

- The water can now be reused to clean biogas
How Water Scrubbing Works

- The raw biogas is compressed, then fed to a ‘scrubbing’ vessel where it is contacted with water. CO2, H2S, siloxanes and other trace contaminants are preferentially absorbed by the water.
- Absorbed methane is ‘flashed’ off, in a vessel at a lower pressure and recovered by returning it to the start of the process.
- Product gas is further purified by a proprietary TSA, before being analyzed and delivered to the customer.
Flotech Water Scrubbing Technology in Focus

- Water used as the scrubbing agent
  - Water scrubbing process upgrades raw biogas to vehicle fuel or pipeline standards efficiently, and with less impact on the environment. Biomethane quality exceeds recognized international vehicle fuel standards and natural gas quality specifications.

- Hydrogen Sulphide
  - Flotech’s innovative, patented “polishing” process is proven to reduce biomethane H2S carryover to less than 1 ppm in the biomethane.

- Siloxanes
  - Flotech’s system removes siloxanes to the levels required for reliable use for internal combustion engines

- Track Record
  - Flotech has the longest and best track record in the industry
High Availability Biomethane Systems

Greenlane biomethane plants have the highest availability in the market.

- Twenty years of experience and seven generations of design have translated into a set of standard systems with no surprises.

- Issues around biogas liquids handling, contaminant fouling, biogas composition variations, etc., have been solved.

- Repeating proven designs with reliable components controlled by verified software is our recipe for eliminating operational risk.

- Remote monitoring and management ensure plants perform as expected.
Key Elements of System Support

Site Assistance

- Installation Support
- Capable Commissioning Personnel
- Performance Validation
- Operator Training

Remote Management

- 24/7 Data Collection and Trending
- 24/7 Phone Support
- Maintenance Packages
  - For 6 and 12 month service
- Callout Support with <48 hr Guaranteed Onsite Response Times
## Greeenlane® Products

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Nominal Capacity Raw Gas</th>
<th>Capacity Range</th>
<th>Estimated Plot Dimensions</th>
<th>Estimated Weight (Tonnes)</th>
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<tbody>
<tr>
<td></td>
<td>Nm3/h</td>
<td>SCFM*</td>
<td>Nm3/h</td>
<td>SCFM*</td>
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<tr>
<td>Totara+</td>
<td>2500</td>
<td>1555</td>
<td>1000 - 2500</td>
<td>620 - 1555</td>
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</table>
Quality Requirements for CNG
Renewable Natural Gas Interchangeability

- Upgraded biogas can be interchangeable with natural gas

Selected standard requirements for grid injection or for utilization as vehicle fuel.

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<tr>
<th>Compound</th>
<th>Units</th>
<th>Reported Tariff Range</th>
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<tbody>
<tr>
<td>Heating Value</td>
<td>Btu/scf</td>
<td>950 - 1000 (min) 1075 - 1200 (max)</td>
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<tr>
<td>Carbon Dioxide</td>
<td>% volume</td>
<td>1 - 3</td>
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<tr>
<td>Nitrogen</td>
<td>% volume</td>
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<tr>
<td>Oxygen</td>
<td>% volume</td>
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<tr>
<td>Hydrogen Sulfide</td>
<td>grains of H2S/100scf</td>
<td>0.25 - 1</td>
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<tr>
<td>Water Content</td>
<td>lb/MMscf</td>
<td>4 - 7</td>
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Source: AGA Report No. 4A - Natural Gas Contract Measurement and Quality Clauses (DRAFT update, 2009)
Making CNG from biogas

Case study - Fair Oaks IN
A Greenlane Totara+ system upgrades 2500 Nm3/hr of biogas to both vehicle fuel and pipeline injection.

The installation is at a large dairy farm in NW Indiana. Anaergia integrated and operates the overall system and the renewable natural gas (RNG) station was installed and operated by Clean Energy Fuels.

Much of the biomethane is used to fuel the dairy trucks delivering the milk, though the fuelling station is open to the public.

The plant was installed in 2012.
Fair Oaks Indiana – Reasons for RNG

- Low Avoided Price for Electricity
- High Gas Output
- Location Close to Fueling Station
- Dedicated Routes
- Dedicated Fleets
- RIN’s
- Tax Credits and Incentives
- Industry Commitment to Sustainability
System Overview

- Fair Oaks Dairy currently operates an anaerobic digester for processing the waste from 11,000 milking cattle
- The system collects biogas from the existing digester
- Biogas is upgrading through a water scrubber to meet pipeline standards
- The biomethane / RNG fuels milk trucks as well as other vehicles
- Fair Oaks Dairy, Anaergia-UTS, Greenlane, Clean Energy and many others involved in the project
Site Overview
Process Overview

Anaerobic Digestion

Electric Generation
300 SCFM
(by others)

Biogas Upgrading System
1,500 SCFM

Biomethane Testing

1,800 SCFM

Secondary Compression and Utility Injection

Fueling Station with Compression

Pipeline

891 SCFM

300 SCFM (by others)
Digester to Upgrading
Biogas Upgrading

Biogas Compression

Biogas Upgrading
Biogas Upgrading

Gas Cooling and Water Chilling

Biomethane PSA/TSA Polishing and Measurement
RNG Compression

Biomethane Compression
CNG / RNG Station

Vehicle Fueling Station
Further Biogas to Vehicle Fuel Sites
Case Study – Madrid, Spain

- Two parallel 2000 Nm3/hr (1200 scfm) Totara systems
- Installed 2009
- Feedstock is a Municipal WWTP biogas.
- Flotech also provided a RC2500 biomethane booster Compressor to 1000 psig
- Produces enough energy to operate up to 250 buses from "Empresa Municipal de Transportes" (EMT); about 20% of its total fleet
- Energy for ~20,000 houses to be supplied or up to 4% of the total demand for industries in the city will be generated.
Case Study – Motala, Sweden

- Typical smaller biogas upgrading unit for vehicle fueling applications, with 80 Nm3/hr (50 scfm) biogas processing capacity

- Biogas from a small wastewater treatment plant (WWTP)

- Small footprint, compact design, while still achieving 99%+ CH4 yield. System shipped and installed in a standard 20’ shipping container.

- Design includes several patent pending innovations

- Biomethane CNG supplies ~250 cars
Case Study – Kobe, Japan

- Biogas from a local wastewater treatment plant (WWTP), with initial biogas 150 Nm3/hr (~90 scfm), then increased to 800 Nm3/hr (500 scfm)

- Biomethane is used to fuel fleet vehicles at a fueling station inside the WWTP’s gate.

- First plant installed in 2004, with two more systems installed in 2006

- Two more Greenlane biogas to CNG systems were installed in Japan in 2011
Hamilton, Ont.

- First wastewater treatment plant (WWTP) biogas to biomethane project in Canada
- 430 Nm3/hr (260 scfm) biogas flow from the Woodward WWTP
- Installed in October 2011
- Union Gas is the gas utility accepting the biomethane, who then supply the City of Hamilton’s CNG refueling stations.
Biomethane / Renewable Natural Gas (RNG)

Compression & Offtake
- Tube Trailers (4000 psi)
- Gas Grid Injection (50-1000 psi)
- Vehicles (3500 Psi)

Polishing

Trace CO₂ Removal
- PSA
  - CO₂ <50 ppm

Liquification To LNG
- Cold Box
- LNG
Lidköping Sweden – Reasons for LNG

- Lower Fuel Transportation Costs
- LNG tankers are much lower cost per distance travelled vs. CNG tube trailers
- Many larger truck engines are designed for LNG
Lidköping Sweden – Biogas to LNG System
Thank You for Your Attention!

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