

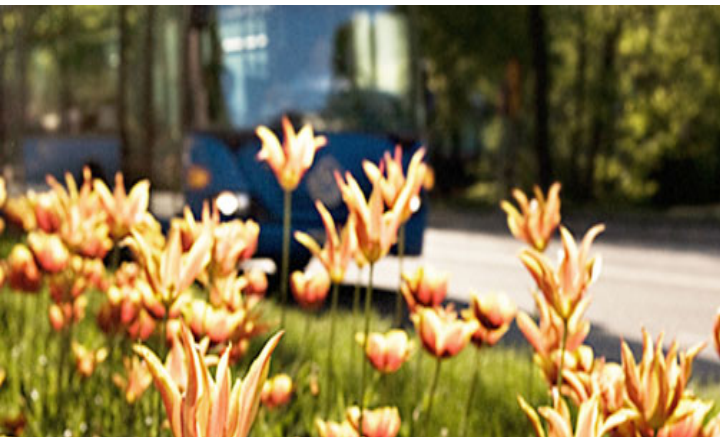


# Tapping into the Transportation Fuel Market

Global Methane Initiative

March 15<sup>th</sup>, 2013

Vancouver, BC





# Greenlane

- 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



Greenlane



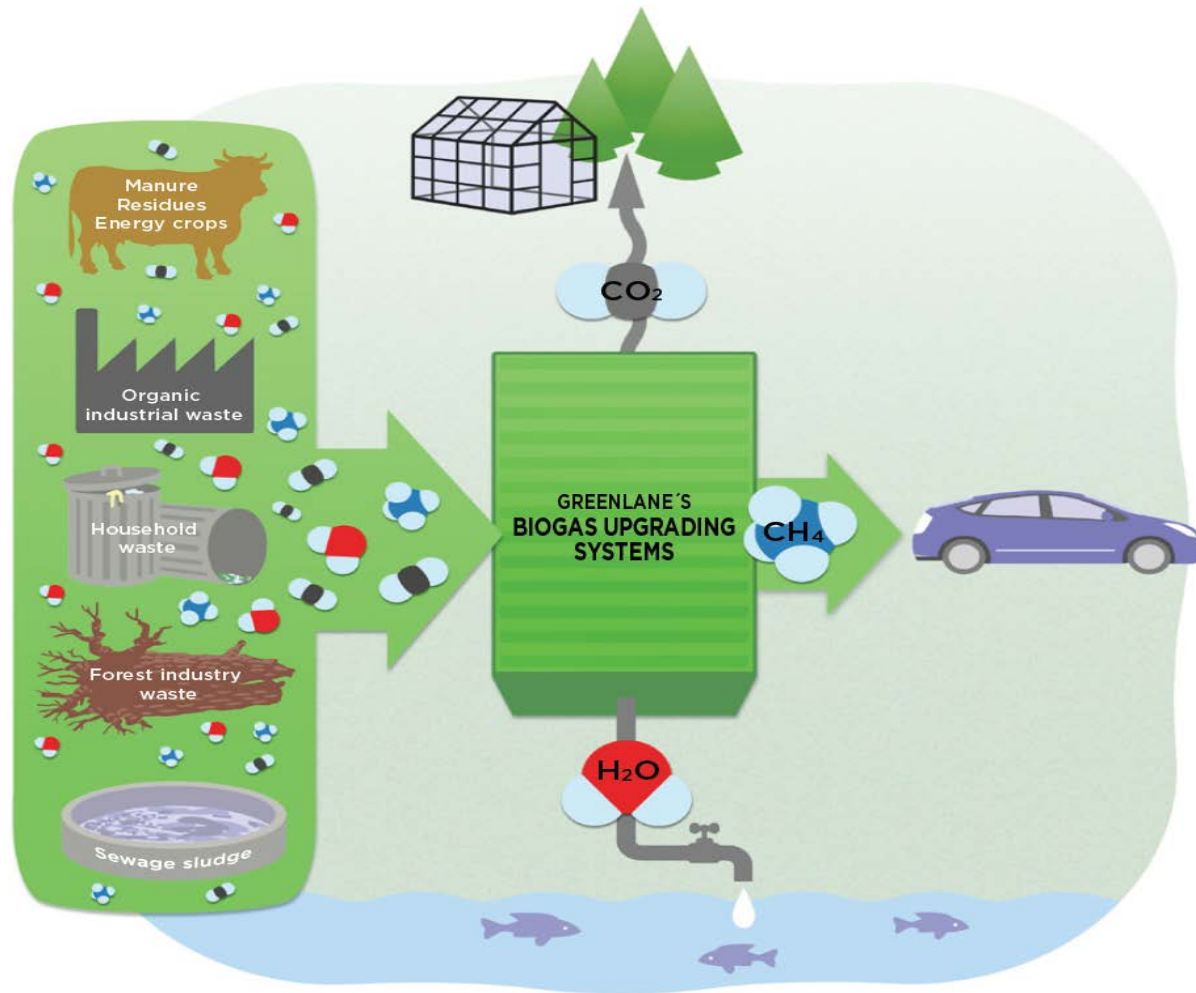
KALLT



AfterCare  
TECHNICAL SUPPORT



# **Biogas Upgrading**



BIOGAS requires upgrading to be used as CNG or LNG Vehicle Fuel

# Biogas Upgrading

- 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

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



## Biomethane

$\text{CH}_4$ : >96%  
 $\text{CO}_2$ : ~1%  
 $\text{O}_2$ : <0.4%  
 Total inerts: <4%  
 $\text{H}_2\text{S}$ : <1 ppm  
 $\text{H}_2\text{O}$ : <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)

8 Gallons

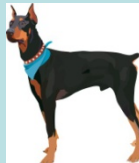
Natural Gas at Ambient  
Pressure  
– 1000 SCF (1 atmosphere, 14.7 psia)



(8 x 8 x 16  
minibus)  
1000 ft<sup>3</sup>

Compressed Natural Gas in a  
Vehicle

(3500 psi) – 1000 SCF  
(238 atmospheres pressure)



4.2 ft<sup>3</sup>  
(31 gallons)

LNG at -260 F  
(666 SCF gas/ CF LNG )

1.5 ft<sup>3</sup>  
(12 gallons)

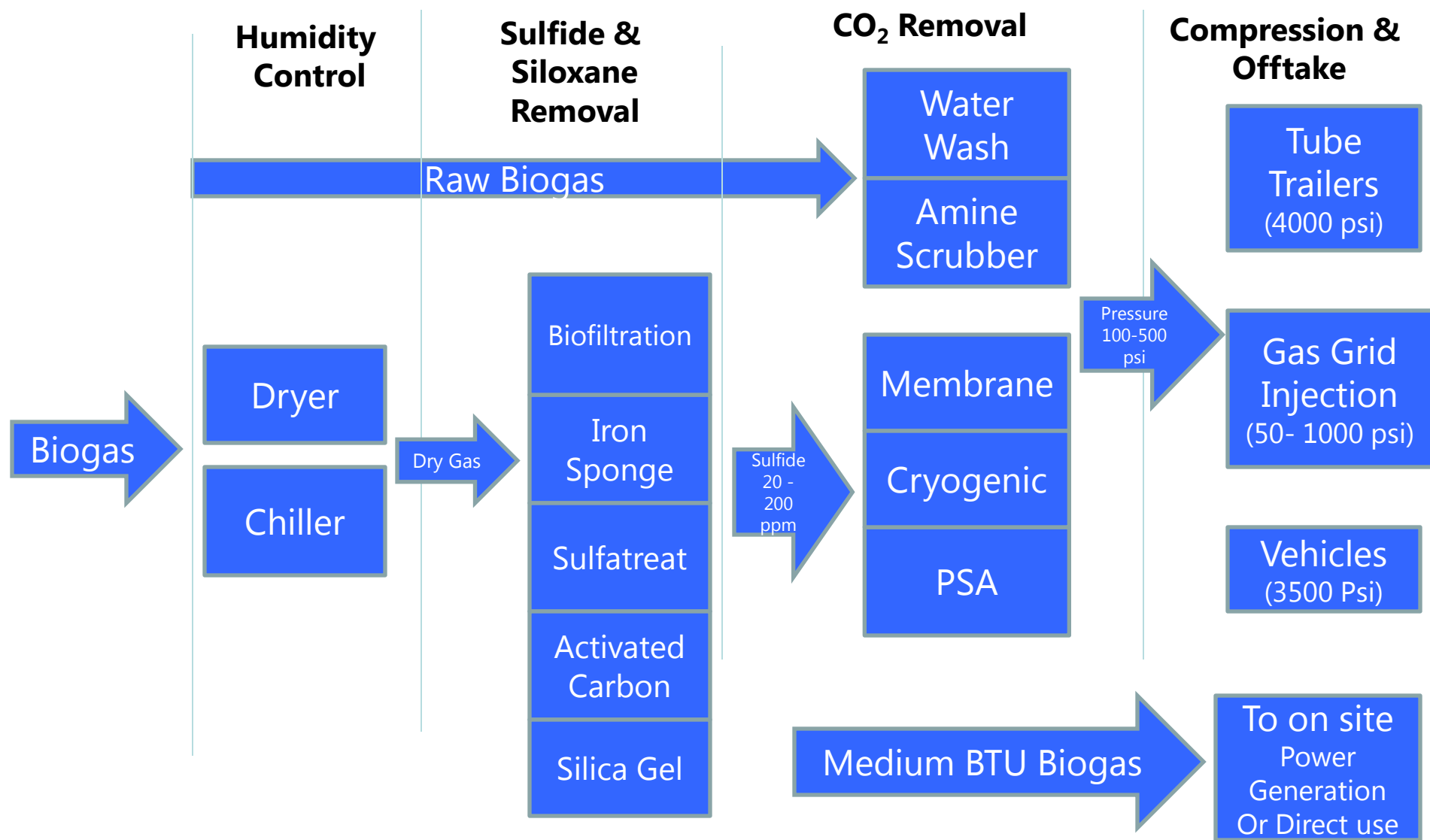




## Distance Travelled on \$10 of Fuel (assuming 25 MPG)

- 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

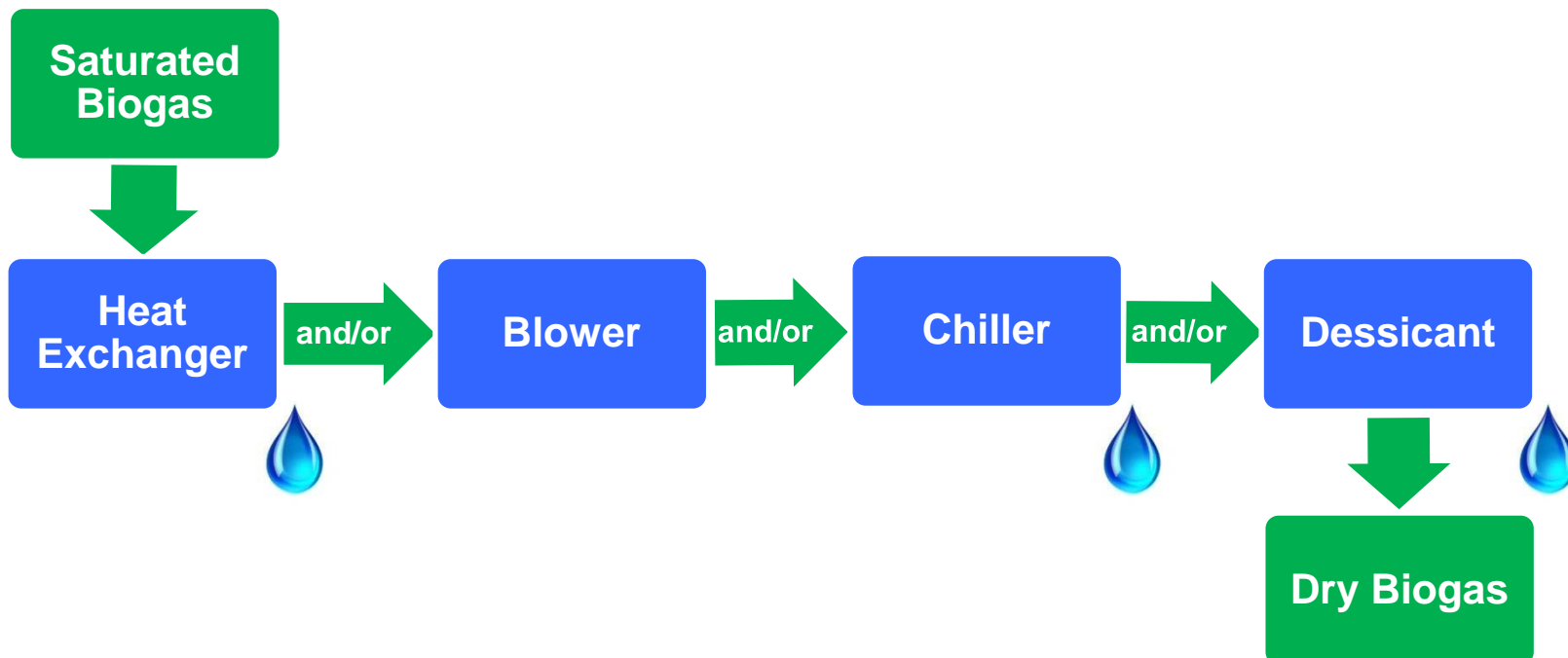
\*\$/Gal of gas equivalent (GGE) = (\$5/MMBTU) X  
(0.13 MMBTU/Gal of gas)





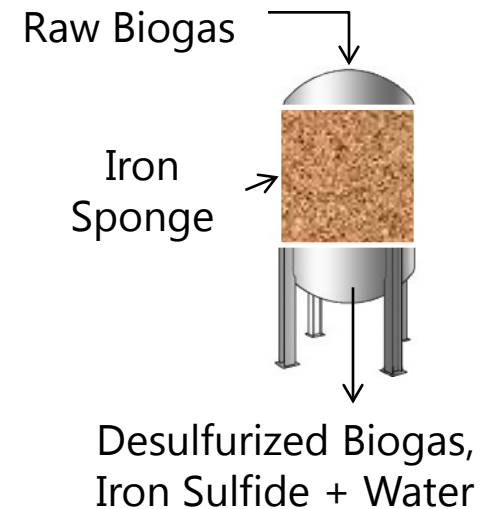
# Biogas Drying

- 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.



# H<sub>2</sub>S 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 (Fe<sub>2</sub>O<sub>3</sub>) reacts with sulfides (H<sub>2</sub>S) to produce iron sulfide (Fe<sub>2</sub>S<sub>3</sub>) and water (H<sub>2</sub>O):  $2 \text{Fe}_2\text{O}_3(\text{s}) + 6 \text{H}_2\text{S}(\text{g}) \rightarrow 2 \text{Fe}_2\text{S}_3(\text{s}) + 6 \text{H}_2\text{O}(\text{l})$
- Must drain excess water occasionally so as not to flood the bed
- Bed can be regenerated several times before needing replacement



# H<sub>2</sub>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

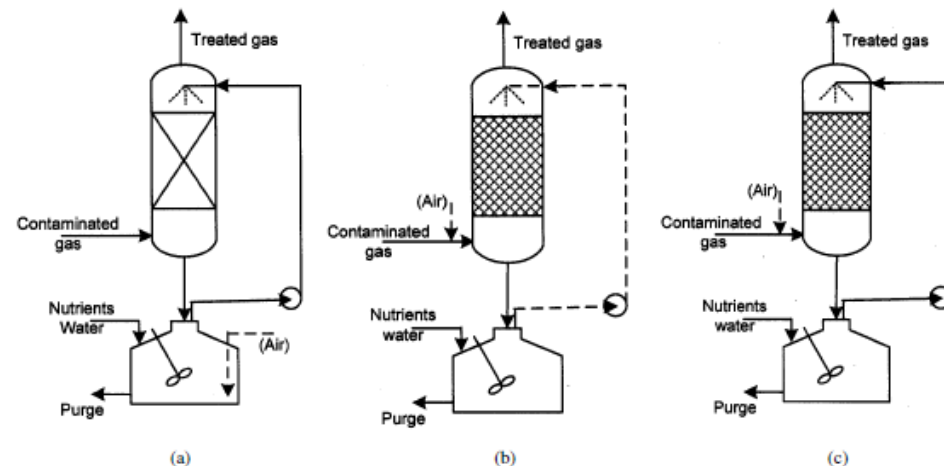
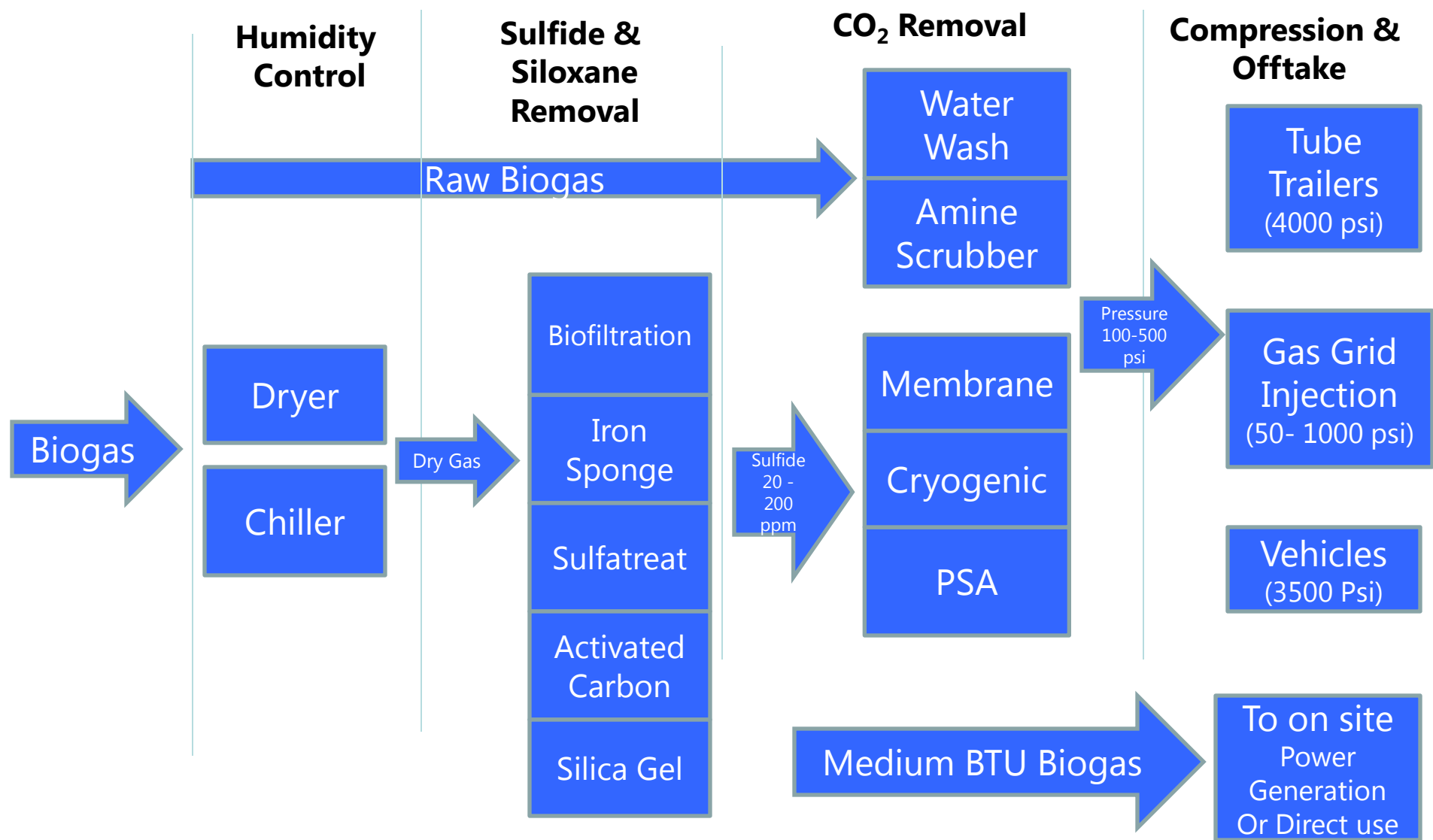


Fig. 5. Systems for removal of H<sub>2</sub>S: (a) bioscrubber; (b) biofilter; (c) biotrickling filter.



## A Simple Concept

- Biogas is primarily methane ( $\text{CH}_4$ ) and carbon dioxide ( $\text{CO}_2$ )
- Water under pressure can be used to separate these two gases through their different solubility in  $\text{H}_2\text{O}$



# Water Regeneration

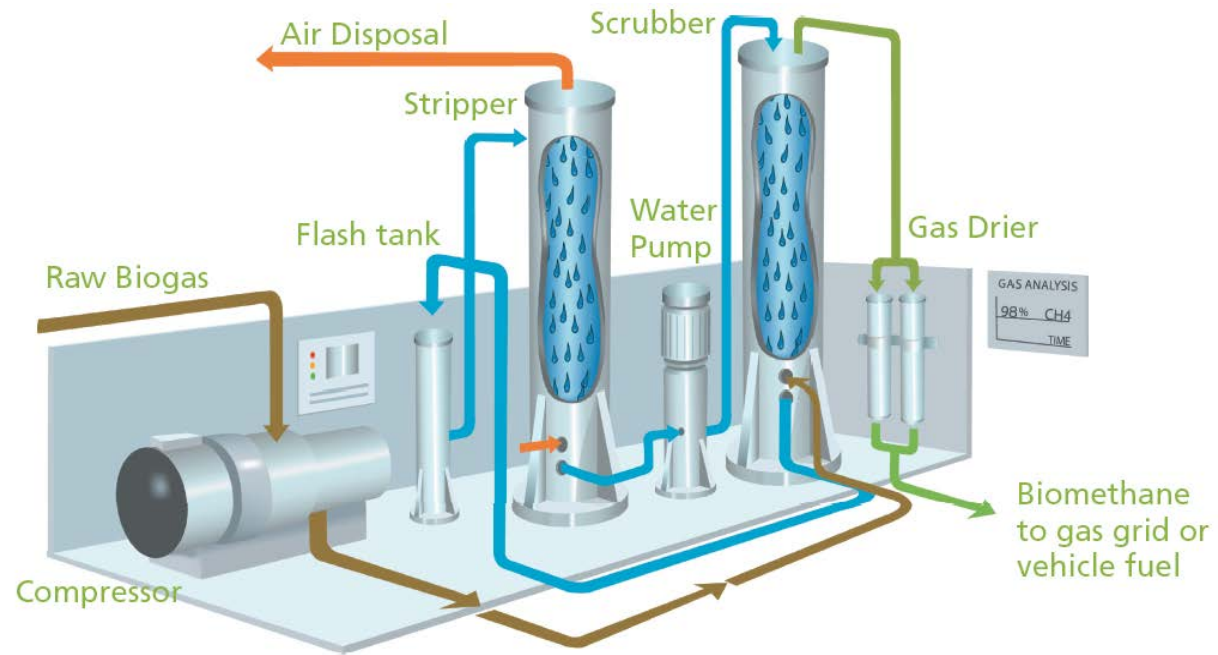
- Water from the scrubber is sent to flash tank to depressurize, so the small amount of absorbed methane can be removed from the water
- The water is then sent to a stripper that removes the gases absorbed in the water



- 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. CO<sub>2</sub>, H<sub>2</sub>S, siloxanes and other trace contaminants are preferentially absorbed by the water.
- Absorbed methane is 'flushed' 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 H<sub>2</sub>S 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



Greenlane® Totara – Scrubber Vessel Installation



Flotech – AfterCare Remote Monitoring



# Greenlane® Products



Model Name	Nominal Capacity Raw Gas		Capacity Range		Estimated Plot Dimensions	Estimated Weight (Tonnes)	
	Nm3/h	SCFM*	Nm3/h	SCFM*	Length x Width	Shipping	Operating
Manuka	80	50	0 - 80	0 - 50	1 x std. 20' container	7	8
Manuka+	130	80	0 - 130	0 - 80	1 x std. 20' container	7.5	8.5
Kanuka	300	185	100 - 300	60 - 185	1 x std. 20' container	9	11
Rimu	800	500	250 - 800	155 - 500	1 x std. 40' container + towers	18	22
Matai	1200	745	400 - 1200	250 - 745	1 x std. 40' container + towers	32	38
Totara	2000	1245	650 - 2000	405 - 1245	1 x std. 40' container + towers	40	48
Totara+	2500	1555	1000 - 2500	620 - 1555	12.2m (40') x 6.9m (22.5') + towers and balance of plant	37	45



# 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.

Compound	Units	Reported Tariff Range
Heating Value	Btu/scf	950 - 1000 (min) 1075 - 1200 (max)
Carbon Dioxide	% volume	1 - 3
Nitrogen	% volume	1 - 4
Oxygen	% volume	0.001 - 1
Hydrogen Sulfide	grains of H <sub>2</sub> S/100scf	0.25 - 1
Water Content	lb/MMscf	4 - 7

Source: AGA Report No. 4A - Natural Gas Contract Measurement and Quality Clauses (DRAFT update, 2009)



# Making CNG from biogas

*Case study - Fair Oaks IN*

## Fair Oaks, IN

- A Greenlane Totara+ system upgrades 2500 Nm<sup>3</sup>/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  
Totara+ System Installation



Greenlane® Totara Compression System  
Fair Oaks, Indiana

# 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



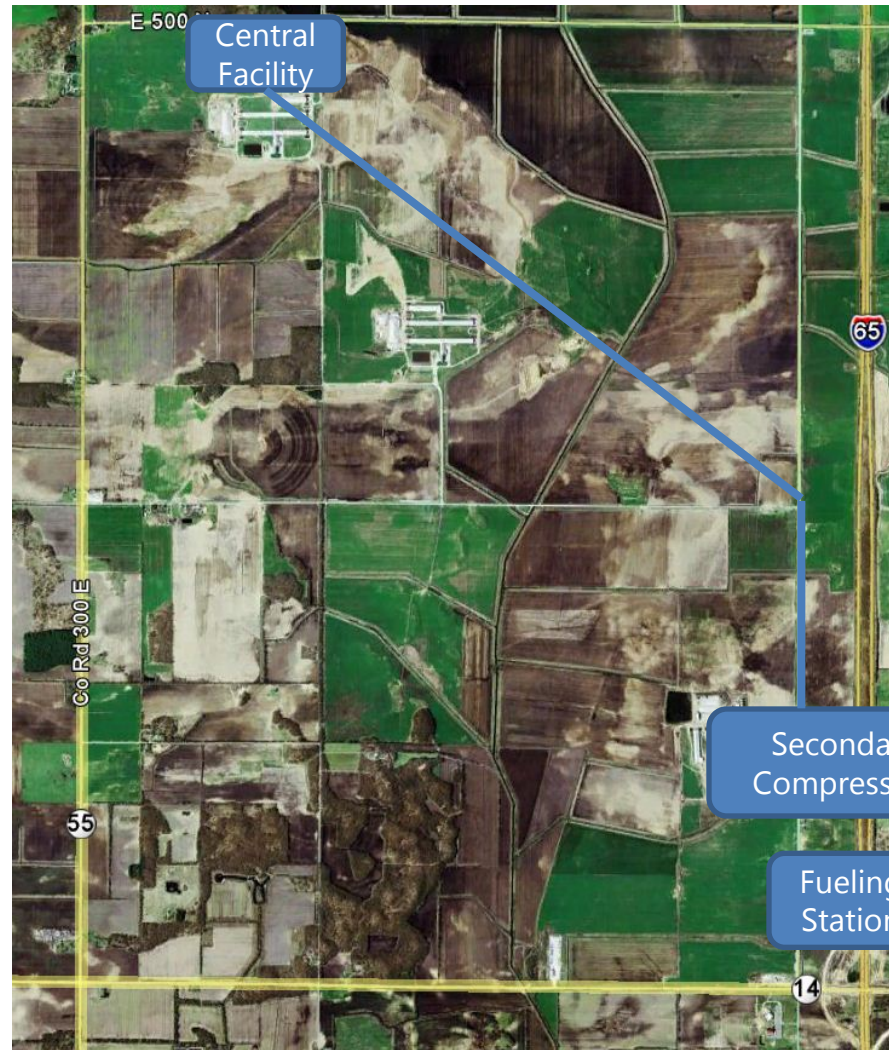


# System Overview

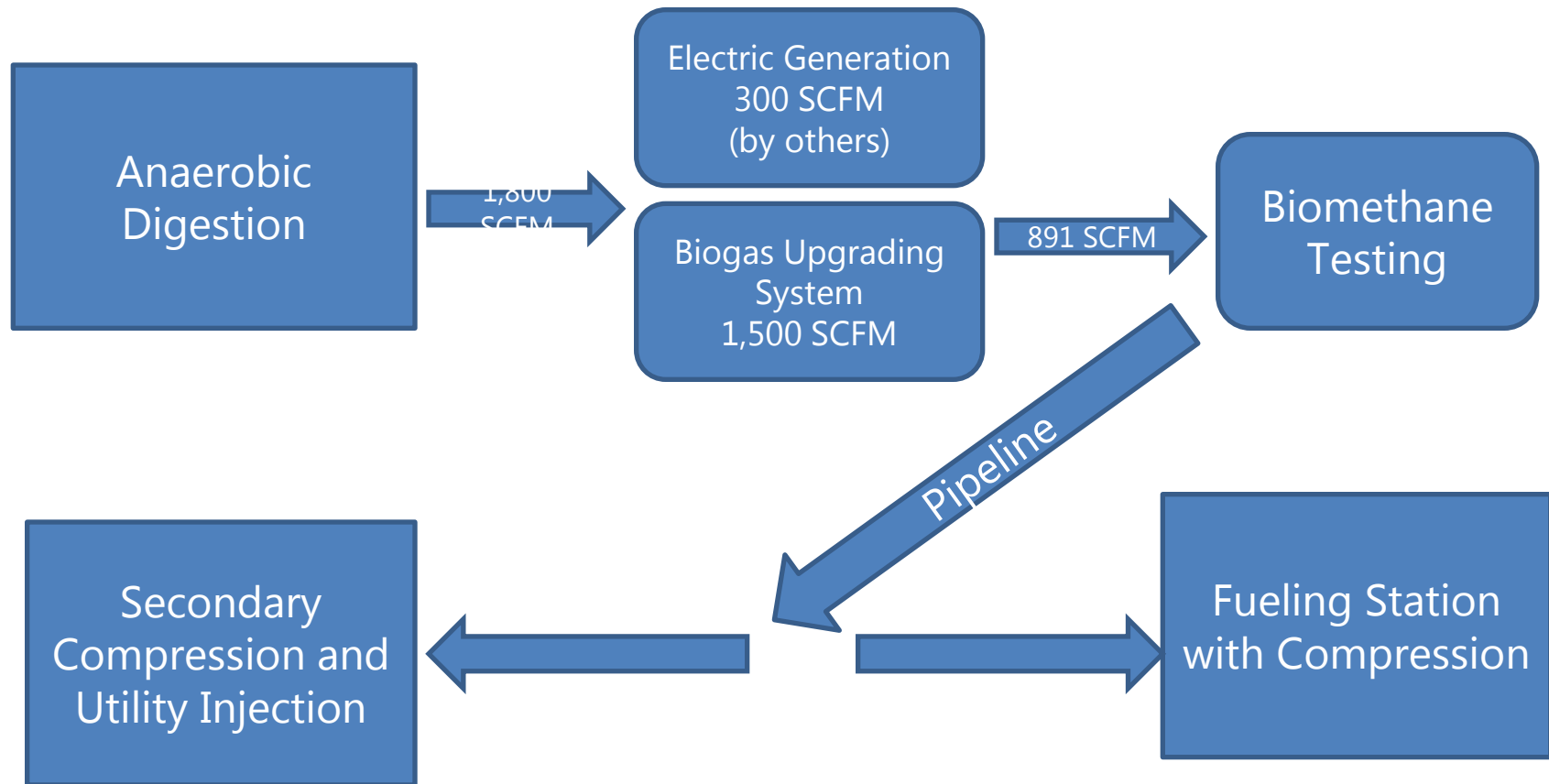
- Fair Oaks Dairy currently operates an anaerobic digester for processing the waste from 11,000 milking cattle
- The system collects biogas from the existing digester
- Biogas is upgrading through a water scrubber to meet pipeline standards
- The biomethane / RNG fuels milk trucks as well as other vehicles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



# Site Overview



# Process Overview



# 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 Nm<sup>3</sup>/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.



Greenlane® Biogas Upgrading Plant –  
Madrid, Spain



Greenlane® Biogas Upgrading System  
Madrid, Spain

## Case Study – Motala, Sweden

- Typical smaller biogas upgrading unit for vehicle fueling applications, with 80 Nm<sup>3</sup>/hr (50 scfm) biogas processing capacity
- Biogas from a small wastewater treatment plant (WWTP)
- Small footprint, compact design, while still achieving 99%+ CH<sub>4</sub> yield. System shipped and installed in a standard 20' shipping container.
- Design includes several patent pending innovations
- Biomethane CNG supplies ~250 cars



Greenlane® MANUKA - Motala, Sweden, Opening Ceremony (2009)



Greenlane® MANUKA - Motala, Sweden  
Opening Ceremony (2009)

## Case Study – Kobe, Japan

- Biogas from a local wastewater treatment plant (WWTP), with initial biogas 150 Nm<sup>3</sup>/hr (~90 scfm), then increased to 800 Nm<sup>3</sup>/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



Greenlane® Biogas Upgrading System - Kobe, Japan (2004)



Greenlane® Biogas Upgrading Plant  
Kobe, Japan (2006)

## Hamilton, Ont.

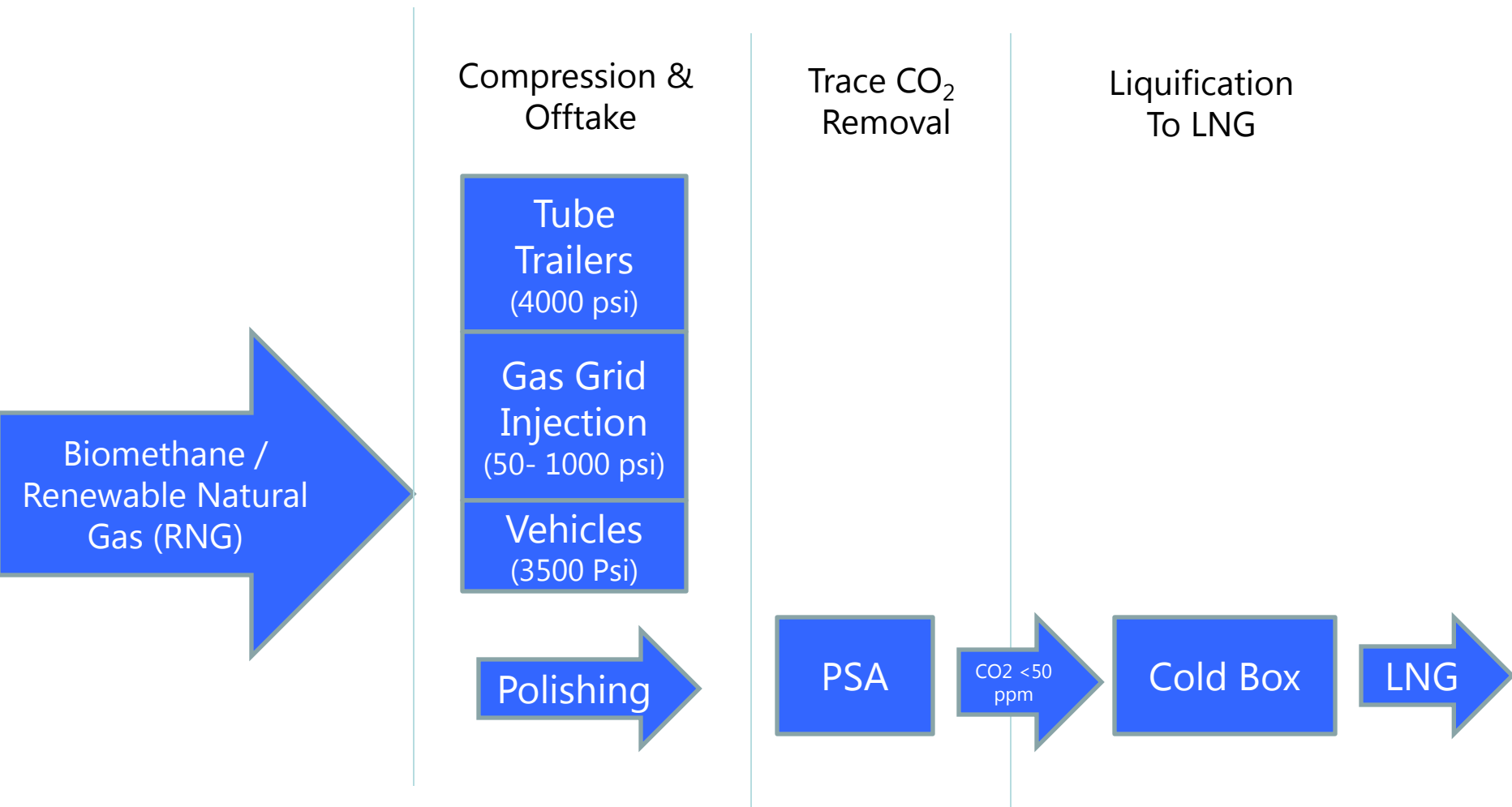
- First wastewater treatment plant (WWTP) biogas to biomethane project in Canada
- 430 Nm<sup>3</sup>/hr (260 scfm) biogas flow from the Woodward WWTP
- Installed in October 2011
- Union Gas is the gas utility accepting the biomethane, who then supply the City of Hamilton's CNG refueling stations.



City of Hamilton, Ontario  
**'Rimu' System Installation**



**Greenlane® Biogas Upgrading System**  
Hamilton, Ontario



# 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

# Digester to Upgrading



Lidköping Sweden – Biogas to LNG System





Greenlane

**Thank You for Your Attention!**

**Ricardo A. Hamdan**

Greenlane Biogas

#102 - 4238 Lozells Avenue

Burnaby BC, V5A-OC4

Cell CA: +1-778-788-0774

Cell US: +1-803-727-4308

[ricardo.hamdan@greenlanebiogas.com](mailto:ricardo.hamdan@greenlanebiogas.com)

[www.greenlanebiogas.com](http://www.greenlanebiogas.com)