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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 CO_2
  - H_2S
  - 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_2S = 25 ppmv to 1,000 ppmv+
  - VOCs are variable

California Air Resources Board (CARB) Primary Standards for CNG

- Methane ≥ 88%
- Oxygen ≤ 1%
- Carbon dioxide + nitrogen ≤ 4.5%
- For LFG, the $CO_2 + N_2 + O_2$ will require CH_4 to be above 95%
- Dew point of 10º 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) ≥ 16,000
- H_2S ≤ 6 ppmv
- Siloxanes ≤ 3 ppmv
- Methane number ≥ 65
- 16,000 Btu/lbm (LHV) ~ 85% CH_4

Acceptable Landfill Gas Characteristics

- CO_2 removal is employed to increase CH_4 content of the landfill gas. An end point CO_2 of 2% is a comfortable target.
- Typical worst case acceptable B-CNG product would be:
  - CH_4 = 85.0%
  - CO_2 = 2.0%
  - N_2 = 12.5%
  - O_2 = 0.5%

Acceptable Landfill Gas Characteristics (cont…)

- Equivalent landfill gas for this product would be:
  - CH_4 = 50.8%
  - CO_2 = 40.6%
  - N_2 = 7.8%
  - O_2 = 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

Parameter	Raw LFG	Product Gas
Methane	54.7%	92.0%
Carbon Dioxide	40.7%	1.4%
Nitrogen	3.9%	6.2%
Oxygen	0.7%	0.4%

% Methane Recovery = 63%

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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

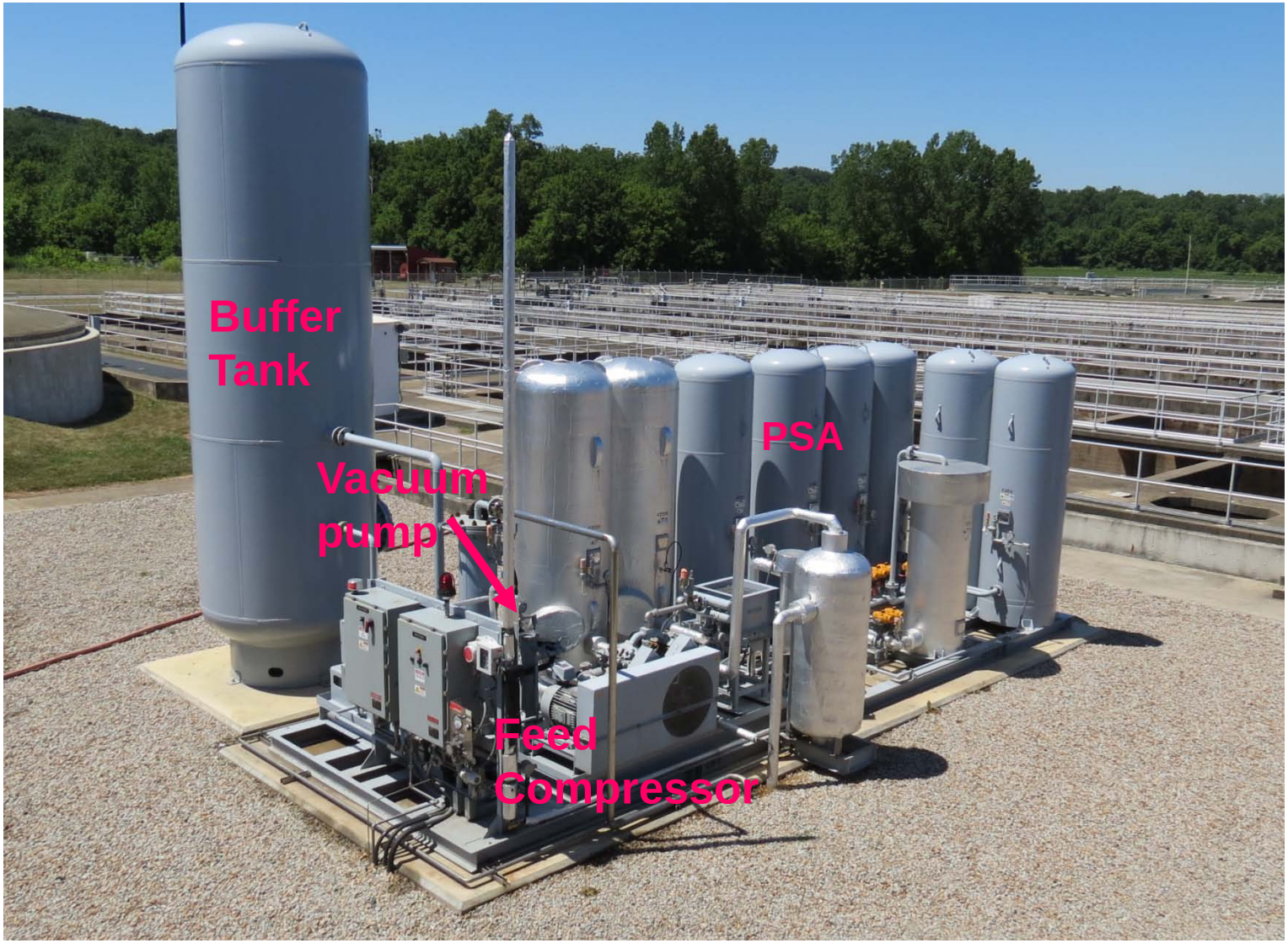
Plant Components

- 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

Parameter	Raw LFG	Product Gas
Methane	51.5%	85.5%
Carbon Dioxide	41.1%	2.0%
Nitrogen	6.9%	11.6%
Oxygen	0.5%	0.9%

Note: Inlet N_2 set at maximum acceptable level to yield a product gas CH_4 level acceptable to Cummins Westport


Buffer Tank
Vacuum pump
PSA
Feed Compressor

Rough Conversion Factors
LFG to Liquid Fuel

- Low CH_4 recovery configuration (65% recovery)
  - 100 scfm LFG = 406 GDE per day
  - 100 scfm LFG = 429 GGE per day
- High CH_4 recovery configuration (90% recovery)
  - 100 scfm LFG = 561 GDE per day
  - 100 scfm LFG = 594 GGE per day

Note: LFG at 55% CH_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