How to Make Renewable Natural Gas
2018 AGA-EPA RNG Workshop

Mark R. Hill – Vice President of Operations
October 23, 2018
DTE Biomass Energy is a full scope developer that owns or operates 21 landfill gas to energy projects, including five renewable natural gas facilities:

- Westside (2001)
- Fort Bend (2014)
- Pinnacle (2002)
- Fresh Kills (early 1980's) (Owned by Dept. of Sanitation NYC)
- Seabreeze (2018)

LFG to RNG project
Other LFGTE project
In 2019 DTEBE will be producing renewable natural gas from at least 8 dairy anaerobic digesters in Wisconsin.

Gas will be purified using membrane technology, compressed, and either directly injected into a pipeline or transferred to a pipeline injection station via CNG trailer.
Agenda

Choosing the right technology

Solving contamination issues

Problems to Avoid
The Disclaimer

• This presentation is not meant to favor one technology or a vendor

• Data presented is what I have seen as "typical". There are several companies making improvements to the systems described that may yield better results than shown

• Every plant, pipeline specification, and landfill is different and the configurations may need to be different from what is shown in this presentation

• Make sure to do your due diligence on any new project
Unless you are filling CNG vehicles without a pipeline, you will need to meet a pipeline specification for delivery via a NG pipeline.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Typical Raw LFG</th>
<th>Manure Based Digester Gas</th>
<th>Pipeline Specification Range (Varies)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTU/CF</td>
<td>450 to 600</td>
<td>520 to 630</td>
<td>900 to 1000</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.05% to 2%</td>
<td>Very low</td>
<td>Zero to 0.3%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>40% to 55%</td>
<td>50% to 40%</td>
<td>Total inert gas no more than 3% to 7%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.5% to 14%</td>
<td>Very low</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>5 – 5,000 PPM</td>
<td>1,000 - 10,000 PPM</td>
<td>Less than 4 PPM</td>
</tr>
<tr>
<td>Water</td>
<td>Fully Saturated</td>
<td>Fully Saturated</td>
<td>5 to 7 lbs/MMCF</td>
</tr>
<tr>
<td>Siloxanes</td>
<td>5-125 PPM</td>
<td>Non Detect¹</td>
<td>Non detect to 4 PPM</td>
</tr>
</tbody>
</table>

Other Considerations: Pipeline pressure, VOC’s, dust, bacteria, gas temperature, hydrogen, Wobbe Index

The largest risk any project has is not being able to make pipeline specification RNG

---

¹ If pure manure – addition of food waste or other waste can produce siloxanes
Carbon Dioxide Removal: There are four “mainstream” competing technologies used to remove CO₂

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membrane System</td>
<td>Polymer membranes with tiny “tunnels” that separate carbon dioxide from methane</td>
</tr>
<tr>
<td>Solvent System</td>
<td>Vessels filled with liquid that absorbs carbon dioxide and lets methane pass through. The solvent is regenerated by releasing the carbon dioxide</td>
</tr>
<tr>
<td>Pressure Swing Absorption (PSA)</td>
<td>Uses an absorbent material (molecular sieve) that separates the carbon dioxide from the methane then releases it when the pressure in the vessel changes</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>Uses large amounts of water to absorb the carbon dioxide, letting the methane pass through</td>
</tr>
</tbody>
</table>
Typical Landfill Gas Pipeline-Quality Membrane System

LFG → Compressor → Dryer → Sulfur removal → Thermal Oxidizer

CO₂ Some O₂ → 1st Stage Membrane → Activated Carbon 
Absorbs impurities

1st Stage Membrane → CH₄ Some O₂ → De-Oxidation Catalyst

2nd Stage Membrane

CO₂ Some O₂ → Dehydration Skid 

H₂O Generated

Pipeline
Dairy Anaerobic Digestion Membrane Plant

Differences vs. LFG Plant

- No siloxanes in dairy derived AD gas (but there may be in food waste), thus no siloxane removal is needed
- Low VOC levels compared to LFG
- High $\text{H}_2\text{S}$ levels require more treatment media or a membrane system that can strip $\text{H}_2\text{S}$
- Lower flows and less equipment result in a compact plant

Pagel’s Ponderosa Dairy – Casco, WI
Typical Solvent System Flow Diagram

LFG → Compressor → Sulfur Removal → Compressor

De-Oxidation Catalyst

CH₄ + O₂ → H₂O + CH₄ Generated

H₂O

Dehydration Skid

VOC’s → Thermal Oxidizer

CO₂ → Solvent Treatment

CH₄

Final Compression → Pipeline

Final Compression → Final Compression

H₂O
Example of a Solvent Plant\textsuperscript{1}

1. Rainbows require additional equipment
Pressure Swing Absorption uses media to absorb and release gases. This process is more energy intensive than others.

Step 1: Absorption
Step 2: Depressurization
Step 3: Desorption
Step 4: Pressurize

4 Tanks each going through a stage in cycle
The water absorption process uses only water to remove the H$_2$S and CO$_2$, may require large amounts of water that may require extensive treatment.
There is no one correct answer on which technology to choose – it is dependent upon your LFG gas quality, pipeline specification, and long term plans.

<table>
<thead>
<tr>
<th>Tech</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membrane</td>
<td>• Simple “black box” technology with few moving parts other than compressors</td>
<td>• Beholden to membrane manufacturer</td>
</tr>
<tr>
<td></td>
<td>• Removes some O\textsubscript{2} – may help meet looser O\textsubscript{2} specs</td>
<td>• 94% methane recovery</td>
</tr>
<tr>
<td></td>
<td>• Historically good on-stream rates</td>
<td>• Activated carbon and H2S removal are expensive</td>
</tr>
<tr>
<td></td>
<td>• Easily expandable</td>
<td>• Membranes do not “like” contaminants</td>
</tr>
<tr>
<td></td>
<td>• Smaller plant footprint</td>
<td>• Separate siloxane removal system needed</td>
</tr>
<tr>
<td>Solvent</td>
<td>• Plant components are widely used in the oil/gas industry – spares are readily available</td>
<td>• Expansion may require new towers and compressors</td>
</tr>
<tr>
<td></td>
<td>• 98 to 99% methane recovery</td>
<td>• Typical Solvent does not remove any oxygen or nitrogen</td>
</tr>
<tr>
<td></td>
<td>• Historically good on-stream rates</td>
<td>• Larger/taller plant footprint</td>
</tr>
<tr>
<td></td>
<td>• Typical solvent removes Siloxanes and VOC’s without needing disposable media</td>
<td>• Does not remove any oxygen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Because of low CH\textsubscript{4} loss, additional fuel needed for TOX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• More things to break (pumps, vacuum blowers, etc)</td>
</tr>
<tr>
<td>PSA</td>
<td>• May remove other components of the gas stream, including some nitrogen and oxygen</td>
<td>• ~95% methane recovery</td>
</tr>
<tr>
<td></td>
<td>• Few moving parts other than valves and compressors</td>
<td>• Pressurization/depressurization/re-pressurization process is energy intensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Leaky valves can create serious issues</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>• Simple process that just uses water</td>
<td>• Uses a lot of water – treatment of water may be costly and complicated</td>
</tr>
<tr>
<td></td>
<td>• ~96% methane recovery</td>
<td>• Large foot print with large vessels</td>
</tr>
<tr>
<td></td>
<td>• Removes some N\textsubscript{2} and O\textsubscript{2}</td>
<td>• Can only handle a certain level of N\textsubscript{2} and O\textsubscript{2}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• More moving parts (pumps, valves, etc)</td>
</tr>
</tbody>
</table>
Choosing the right technology

Solving contamination issues

Problems to Avoid
Siloxane removal is needed for membrane systems and potentially others. Regenerative systems are usually paired with an activated carbon polisher.

### Regenerative

- High rate of siloxane removal if proper sizing and media is selected. However, it is not 99.9% effective – which is sometimes necessary to achieve.
- One vessel in service while others are being purged using LFG and/or air. Often these tail gases require a flare/TOX.
- Additional electric load and compression needed, as is gas drying.
- System needs to be tuned and tested for siloxane removal effectiveness.

### Non-regenerative

#### Activated Carbon

- Highly effective at removing nearly everything – including siloxanes.
- Expensive if the sole means for removing siloxanes.
- Other impurities, such as H2S, can reduce effective life of activated carbon that is targeting siloxane.
- Free liquids can reduce effectiveness of media.
Hydrogen Sulfide (H$_2$S) Removal

Non-NRU plants (very low O$_2$ in inlet gas)

Typically use Sulfurtrap, Sulfatreat, Darco BG-1, activated carbon or similar disposable media.

Can be very expensive if inlet H$_2$S levels are high—factor this into economics of a project.

Ensure you have a backup vessel so that you are able to meet pipeline quality if media becomes exhausted.

Sulfur removal vessels at a Solvent plant

NRU Plants (moderate O$_2$ in inlet gas)

Iron sponge media being loaded into vessels.

Can use any of the removal systems shown with non-NRU plants.

May also explore using a less expensive iron-sponge media that is mounted on wood chips. This system requires low levels of oxygen, which would not be compatible with a non-NRU plant.

1. Darco BG-1 requires an approximately 4:1 Oxygen/H2S ratio
An oxygen removal system is necessary if you have to hit a tight oxygen specification.

Typical system uses palladium or platinum catalyst at high temperatures.

The oxygen and methane molecules react on the catalyst, form water, and strip out the oxygen from the gas stream.

Dryer needed to remove water created by the process.

Necessary at some sites with tight pipeline specifications, but expensive and energy intensive.
Nitrogen Removal Unit (NRU)

Typically uses pressure swing absorption technology to absorb CH\textsubscript{4} and let N\textsubscript{2} pass through and be vented/treated (other technologies than PSA exist)

Expensive to build and very energy intensive

Designed around a specific nitrogen amount and if that amount is exceeded the plant capacity rapidly drops

Methane yield drops to upper 80%’s due to methane slippage in NRU.

DTE Biomass Energy prefers to prevent nitrogen intrusion in the wellfield rather than go through the expense of removing it at the plant. However, if this is not possible, an NRU will be necessary to meet “tight” pipeline specifications.
If your plant is falling short of a high BTU/CF pipeline specification, there are a few things you can do:

1) Fix the wellfield! Many cases where a plant fails to meet the BTU specification emanate from atmospheric intrusion into the gas collection system. **Having a well-run, low atmospheric intrusion wellfield is the most important part of a successful RNG project**

2) Expensive equipment (eg. amine unit or NRU) to remove remaining carbon dioxide or nitrogen

“Tight” pipeline specifications often create more energy usage and costs to meet the required specification. Pipeline transmission companies that offer more tolerant specifications will attract more RNG projects with stronger environmental benefits
Agenda

Choosing the right technology

Solving contamination issues

Problems to Avoid
Producing pipeline quality gas from landfill gas is really easy to mess up…

“Learn from past mistakes – preferably someone else’s” - Fred Brooks (IBM Computer Architect)

Many projects fail due to poor quality of gas from the wellfield
• NRU’s are not “bulletproof” and require moderate levels of Nitrogen
• Oxygen intrusion and poor methane quality will make RNG production near impossible regardless of technology used
• Developers frequently want control of the wellfield to ensure their tens of millions of dollars spent on the plant are not wasted. With the right developer, this can lead to continued NSPS compliance, lower electric usage (no NRU needed), and higher royalty payments (a larger pie to share)

Hire the right operations team
• Typically a very small team that has to be good at everything
• Do not be “cheap” with poor quality wellfield technicians – they are the most important component to a successful project
• Ensure you have an instrumentation and controls tech and a compressor tech
• Manager needs to be multifaceted – environmental compliance, knowledge of commercial contracts, and knowledge of both plant and wellfield are key
Pitfalls to avoid

Metering LFG is very difficult
- Must take into account specific gravity changes, moisture content, heat, pressure, etc.
- Failure to properly place, program, calibrate, and record flow data can jeopardize creation of RIN’s and LCFS

Build redundancy around media vessels and be ready for more pressure loss
- Activated carbon and sulfur removal media may be exhausted prematurely, make sure to have back-up vessels ready
- As media ages, differential pressure frequently increase. Build in additional compression capacity to take this higher differential pressure into account

Do not undersize the NRU (if needed)
- If the NRU is built for 4% nitrogen, and you experience 14% nitrogen, plant capacity could be cut in half
Feel free to contact our team with further questions

Mark Hill
Vice President of Operations
Mark.Hill@dteenergy.com

Kevin Dobson
Vice President of Business Development
Kevin.Dobson@dteenergy.com

Visit us at [www.dtebe.com](http://www.dtebe.com)